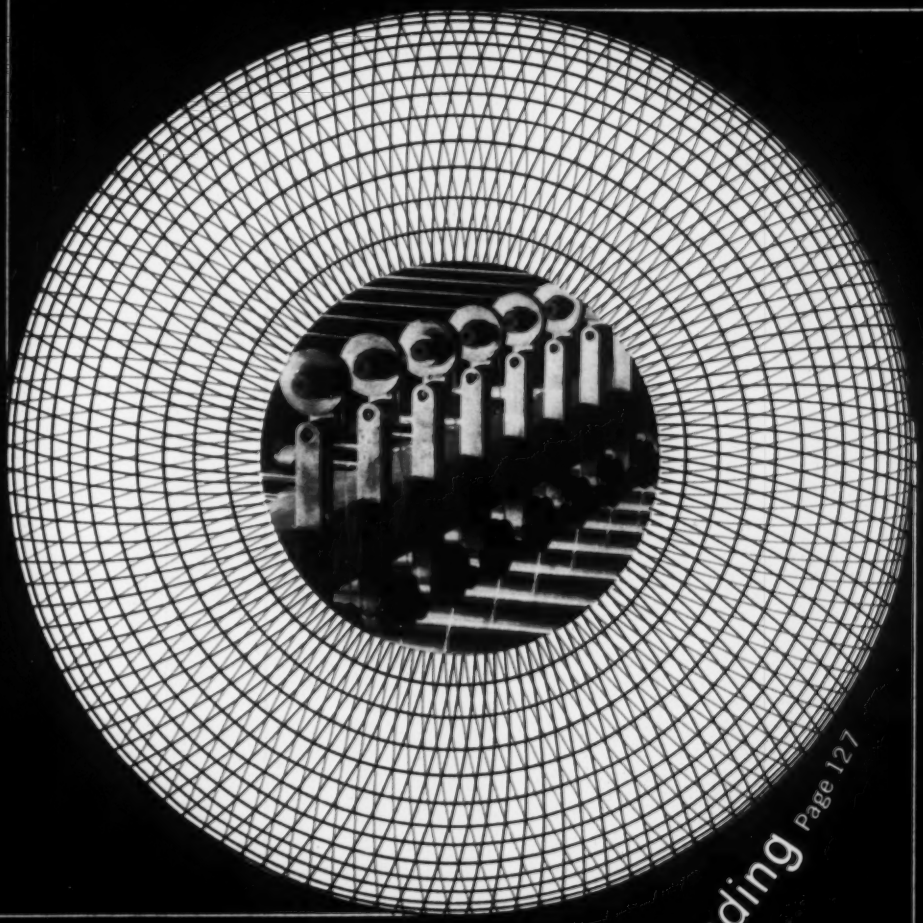
Materials
in Design Engineering



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AUGUST, 1960

(Advertisement)

NEW IDEAS IN COPPER ALLOY ROD AND WIRE

Interesting things happen when you add a spot of zirconium or chromium to copper—four high-conductivity coppers that boost production, cut cost of machining—even plain old free-cutting brass rod is going fancy.

There's a quiet revolution going on in copper metallurgy. Research and development teams are expanding the useful knowledge of copper and copper alloys in an effort to define the properties most suitable for specific engineering applications.

STABILITY at elevated temperature, combined with good electrical conductivity, is probably a combination most sought after by design engineers and by our industry's research teams. Two alloys are now commercially available, and the alloy systems are unique. Chromium copper and zirconium copper are heat-treatable alloys with good stability of mechanical properties up to temperatures in the order of 600 F.

CHROMIUM copper in the fully heat-treated condition following a solution anneal will exhibit properties combining a tensile strength of about 75,000 psi with conductivity of approximately 80% IACS. Zirconium copper has good stability characteristics at elevated temperatures and conductivity of 90 to 95% IACS; the strength properties developed by heat treating are, however, somewhat lower than chromium copper.

SEVERAL other heat-treatable copper alloys with intermediate properties are gaining recognition in the connector and electronics fields. These alloys fall into a conductivity range of 35 to 65% IACS, with tensile strengths 90,000 to 100,000 psi. The most popular alloy systems are the copper-nickel-phosphorus and copper-nickel-silicon series with modifications for free machining or other specific requirements. These alloys have a solution annealing temperature about 100 to 200 C lower than the chromium and zirconium coppers.

THE WIDESPREAD use of panel or harness construction for linking segments of electrical control devices has made the requirement for free-cutting coppers mandatory. Screw machine shops are fabricating these connector components of various designs by the millions. Currently the most popular free-cutting coppers are leaded copper with conductivity of about 98% IACS, and tellurium and sulfur coppers at about 95% IACS. Some of these free-cutting coppers have residual oxygen and can become brittle or gassed under the usual conditions contributing to this phenomenon. All, however, can be obtained with a combination of deoxidizers or oxygen-free copper. In the case of the deoxidized variety, some slight sacrifice in conductivity will be noticed. Ordinary usage very seldom requires conductivity in excess of 90% IACS—and this presents no problem for these coppers.

ALL of these coppers can be cold worked without too much trouble. They can be supplied in a suitable wire temper for cold heading and secondary operations designed around the basic alloy system. Up to now there has not been too much interest in these alloys for wire forming or heading operations. Close dimensional tolerances may be the reason for the reluctance of the heading people to get into the electrical connector business. Alloys are available with the ductility and mechanical properties necessary for this type of forming. It would appear that some of the products could be made more economically by cold-heading or wire-forming operations.

RECENT TRENDS have also affected the old brass and copper reliables. There can't be any product more prosaic than free-cutting brass rod; it is the cheapest of such commodities and at one time was the easiest to process—all one had to do was to extrude, draw to finish dimensions, and ship. In many cases this practice won't work today. Deep drilling, roll threading, knurling, staking, slotting, etc., have complicated the picture, but the latest efforts of the screw machine builders have laid this ghost to rest. We now hear of beta-free rod for close tolerances on deep-drilling applications. Similar grain structures, but not necessarily the same temper, are required for roll threading, knurling and staking or whenever extra ductility is needed. Along with the consideration of grain structure, it has been necessary to take advantage of the broad chemical composition range for free-cutting brass. Most suppliers divide the standard range into two parts, utilizing the lower copper range for the larger sizes that will normally be machined on the heavier, faster screw machines where chip breaking and clearing the tools are the most important considerations. This might be considered the rough, breakdown type of stock.

FOR the smaller diameters, specialization has been the watchword. Depending on specific needs, you can now obtain free-cutting brass rod with all-alpha, fine-grained structure or an alpha-beta fine-grained extruded structure, or possibly a combination of both. For certain applications you might need a coarse-grained, all-alpha structure. Lead dispersion and lead content are other variables that can and will be controlled to meet fabricating or end-use requirements.

IN the cold-heading industry, advantage is being taken of the wider selection of copper and copper alloys that is available today. The nickel silvers, phosphor bronzes, and silicon bronzes combine good ductility and high strength with excellent corrosion resistance. The whole range of common brasses has specific applications and can be tailored to various heading operations.

The research and development hopper is full of interesting new ideas and projects at The American Brass Company. It could be that we're working on something which would help solve one of your problems. Even though we don't have the complete answer, perhaps we could both reach a solution faster by pooling our efforts. Call your American Brass representative and talk it over with him or write: Manager, Market Planning, The American Brass Company, Waterbury 20, Conn.

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AUGUST 1960 | VOL. 52, NO. 2

Materials in Design Engineering

FORMERLY MATERIALS & METHODS

APPLICATION OF METALS, NONMETALLICS, FORMS, FINISHES

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REINHOLD PUBLISHING CORP.
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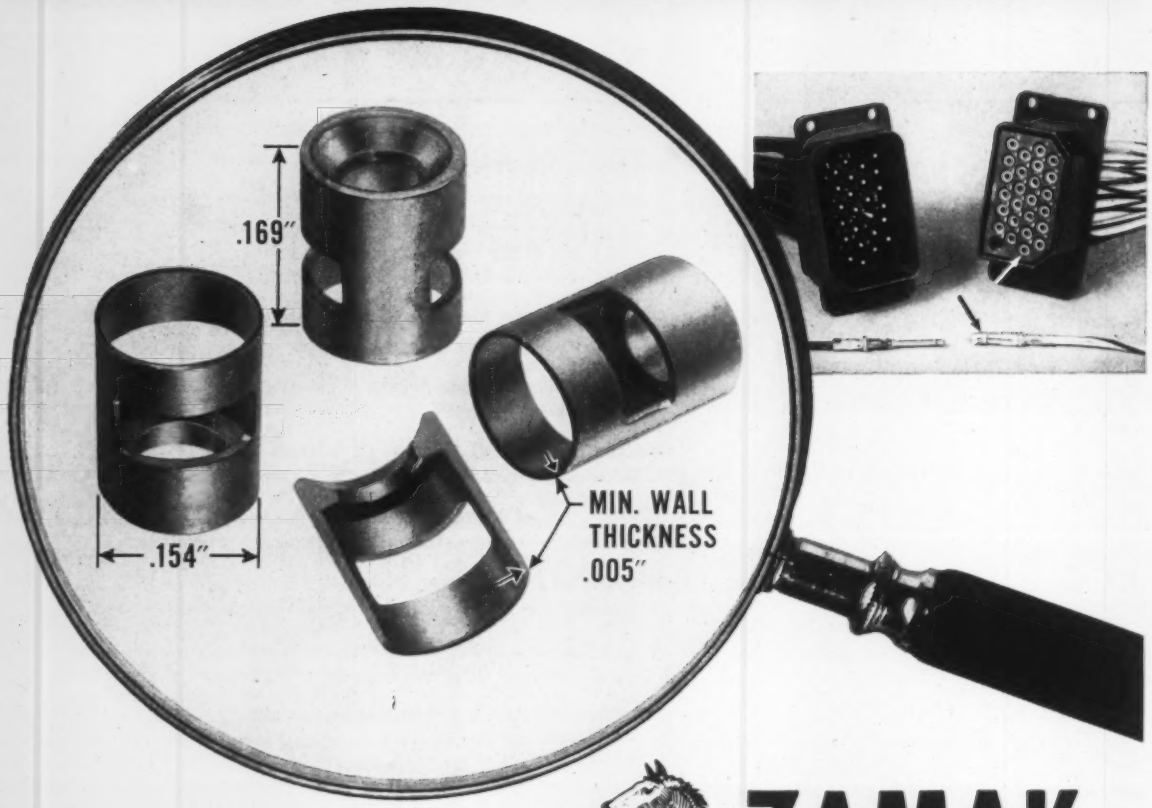
IT'S LIGHTER THAN YOU THINK!



WHEN DIE CAST with ZAMAK

These tiny zinc die cast electrical contact socket cups have a minimum wall thickness of .005"—**the thinnest wall section ever die cast.** Designed by Omaton Division of BURNDY CORPORATION, they more than meet Government specifications and are adaptable for many types of solderless multi-contact connectors.

It takes 10,371 of the smallest cups to weigh a pound and they are 20% lighter than the ones formerly made from drawn steel. Each is precision die cast to a remarkable degree of uniformity and accuracy, despite the complex design.

Such extremely thin-wall sections—possible only with zinc die castings—**frequently eliminate competition from all other materials and production methods.** In addition, ZAMAK zinc die castings provide many more advantages—and all at lower cost.

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General Railway Signal Company designed this Locking Dog for its Type K Interlocking Relay used to control railroad crossing signals.

It was formerly made of extruded brass, sawed to thickness, drilled, profiled, filed, polished and plated at a total cost of $2.20 per piece.

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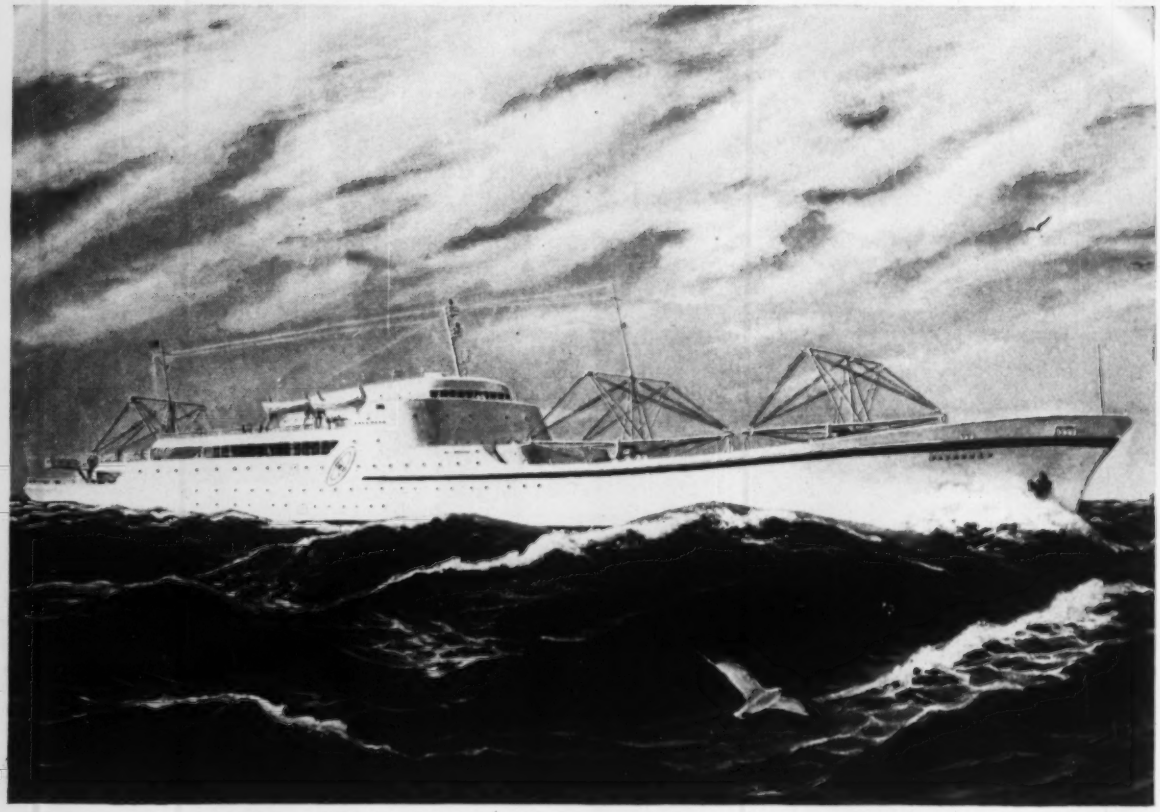

N.S. Savannah, built by New York Shipbuilding Corporation, can sail for three years on 138 pounds of nuclear fuel. A conventional ship would burn 80,000 tons of oil.

'round the world 13 times with fuel to spare ...the first nuclear-powered merchant ship

This is the Nuclear Ship Savannah, first of her kind. Capable of sailing over 350,000 nautical miles without re-fueling, she points the way to a new era in transport and travel at sea.

Her uranium oxide fuel is packaged in tubes of Nickel Stainless Steel...*more than 5,000 of them.* The fuel-element cans that hold these tubes are also made of this strong, corrosion-resisting metal.

Wherever you look, inside the reactor, almost everything is Nickel Stainless Steel. 200,000 pounds of it are used in the reactor area: for the lining of the reactor vessel, for the coolant pumps and tubing that circulate corrosive "hungry" water, and for the control rods inside the atomic pile.

At the design stage, engineers anticipated the high operating pressures—1,750 pounds per square inch—and temperatures up to 508 °F. They selected Nickel Stainless Steels to provide the strength and resistance to heat and corrosion needed to withstand these rigorous conditions.

So the next time you need more from a metal, remember the N.S. Savannah. Nickel Stainless Steel, or another Nickel alloy, may be the solution to *your* problem, too.

A note to Inco will bring you "First Steps Towards Solving Specific Corrosion Problems" and "High Temperature Worksheet"... simplified forms you can use to describe your metal problem. Perhaps our technical staff has information that will help you find the solution.

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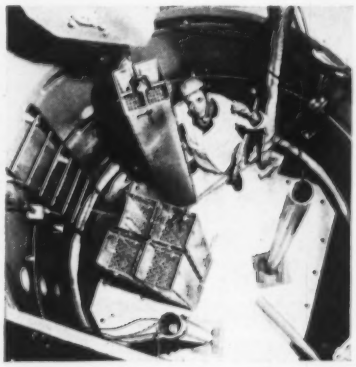

Inside the reactor nearly everything you see is Nickel Stainless Steel to withstand corrosion, high temperatures and pressures that hit 1,750 psi. Reactor built by Babcock & Wilcox Co., Barberton, Ohio.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

For more information, turn to Reader Service card, circle No. 362

What's new IN MATERIALS

...AT A GLANCE

One of stainless steel's biggest drawbacks—poor weldability—has apparently been overcome by altering the chemical composition of some basic stainless steels. Studies show that substantial amounts of manganese decrease the hot cracking susceptibility of stainless steel and thereby increase weldability. On the other hand, titanium and columbium, frequently added to high strength, high temperature stainless steels, are strong promoters of hot cracking. The experimental manganese-containing steels are said to have high strength, good heat resistance and good ductility.

Source: F. C. Hull, Westinghouse Electric Corp., Box 2278, Pittsburgh 30.

A new type of leather is made by taking hides apart chemically and putting them back together again. The developer says the new material, which is still in the experimental stage, could possibly be molded into luggage, handbags and other products. A manufacturing advantage claimed is that the entire hide may be used; conventional tanning processes require extensive trimming of irregularly shaped hides.

Source: Armour Leather Co., Div. of Armour & Co., 426 Randolph St., Chicago.

Ductile, ultra-pure refractory metals are now available in the form of single crystals from two companies. One company's single crystals measure ⅛ in. in dia by 8 in. long and sell for $55 per in. The other company's product, similar but larger, is described on p 13 of this issue.

Source: Materials Research Corp., 47 Buena Vista Ave., Yonkers, N. Y., and Linde Co. (p 13).

Plasma-sprayed coatings of low melting materials such as powdered epoxy resins, and lead and zinc metal powders, can be obtained by using a new device that operates over the temperature range 300 to 30,000 F. Until now, plasma spray devices (see M/DE, Feb '60, p 180 and Mar '59, p 133) usually operated over a much higher temperature range.

Source: Plasmadyne Corp., 3839 S. Main St., Santa Ana, Calif.

Magnet wire coated with a new urethane enamel is said to have fast solderability, good cut-through resistance, and good resistance to solvents, including acetone. Soldering time for a No. 29 AWG wire coated with the enamel is 2 sec at 685 F, or about half the time required for conventional enamels, according to the producer.

Source: Carwin Co., Polymer Products Div., North Haven, Conn.

A new group of aluminum-iron-nickel alloys are said to withstand the "sharply deteriorating effect of high purity water at temperatures up to 700 F." One big use for the alloys will probably be as cladding for uranium fuel rods in atomic reactors. The alloys are still under development.

Source: Aluminum Co. of America, 1501 Alcoa Bldg., Pittsburgh 19.

Intricately-shaped investment castings weighing up to 100 lb are now commercially available. The large castings are made by an improved ceramic shell process in which a mold is made by building up successive monolithic ceramic layers

around a wax, or wax and plastics, pattern. The castings are said to have a finer grain structure and a better surface finish than solid mold investment castings which are usually limited to very small sizes.
Source: Arwood Corp., 321 W. 44th St., New York 36.

Self-sealing graphite-base materials that spontaneously form their own protective coating against heat and oxidation are now being evaluated for possible use in missiles and rockets. The coating, which appears as a smooth, adherent, nonporous, yellowish-brown film, thickens and becomes more resistant as temperature and exposure to oxidation increases. A typical material contains 50% (by weight) graphite, 24% molybdenum disilicide, 25% titanium boride, and small percentages of other ingredients to promote bonding.
Source: J. DiLazzaro, Boeing Airplane Co., Aerospace Div., Seattle, Wash.

A new columbium alloy is bidding for high temperature service. Still under development, the alloy is said to have fairly good ductility at room temperature, good thermal shock resistance, a room temperature tensile strength of 100,000 psi, and reasonably good resistance to oxidation at high temperatures. The alloy contains 10% molybdenum, 10% titanium, balance columbium.
Source: E. I. du Pont de Nemours & Co., Inc., Pigments Dept., Wilmington, Del.

Columbium-uranium alloys show promise as metallic fuel element for small-size nuclear reactors of the future. Reason: a columbium alloy containing 20% uranium by weight has shown excellent tensile strength and hardness properties at temperatures in the 1600 F range. By contrast, present-day metallic fuel elements swell and are unserviceable above 1200 F. Small-size reactors are likely to find use in portable electrical power generators and in spacecraft and ship propulsion systems.
Source: J. A. DeMastery, Battelle Memorial Inst., 505 King Ave., Columbus 1, Ohio.

Gas plated aluminum coatings have been applied successfully to copper. Pure, lustrous and ductile aluminum in thicknesses up to 4.7 mils was deposited by thermally decomposing vapors of tri-isobutyl aluminum on the surface of cleaned, heated copper test panels in a heated plating chamber. (For more information on gas plating, see M/DE, Jan '60, p 98.)
Source: Rpt. No. PB 151923, Office of Technical Services, Dept. of Commerce, Washington 25, D. C.

Fast-curing phenolic molding powders—said to have overall curing rates averaging 25% faster than those of conventional fast-curing powders—are now available. The powders are designed for both cold-powder automatic molding and preheat compression and transfer applications. Potential uses: electric iron handles, socket bases, fan motor housings and switch covers.
Source: General Electric Co., Chemical Materials Dept., 1 Plastics Ave., Pittsfield, Mass.

Look for new and interesting superconductive alloys to make their appearance in the next few years. Reason: a newly developed process shows promise of turning out such hard-to-form alloys as germanium-silver, gold-silicon and copper-silver. The method produces new alloys by blasting molten droplets of pure metals against the rim of a refrigerated metal wheel spinning at high speed. The droplets freeze into small pieces of thin foil before the atoms have time to realign themselves.
Source: P. Duwez, California Inst. of Technology, Pasadena, Calif.

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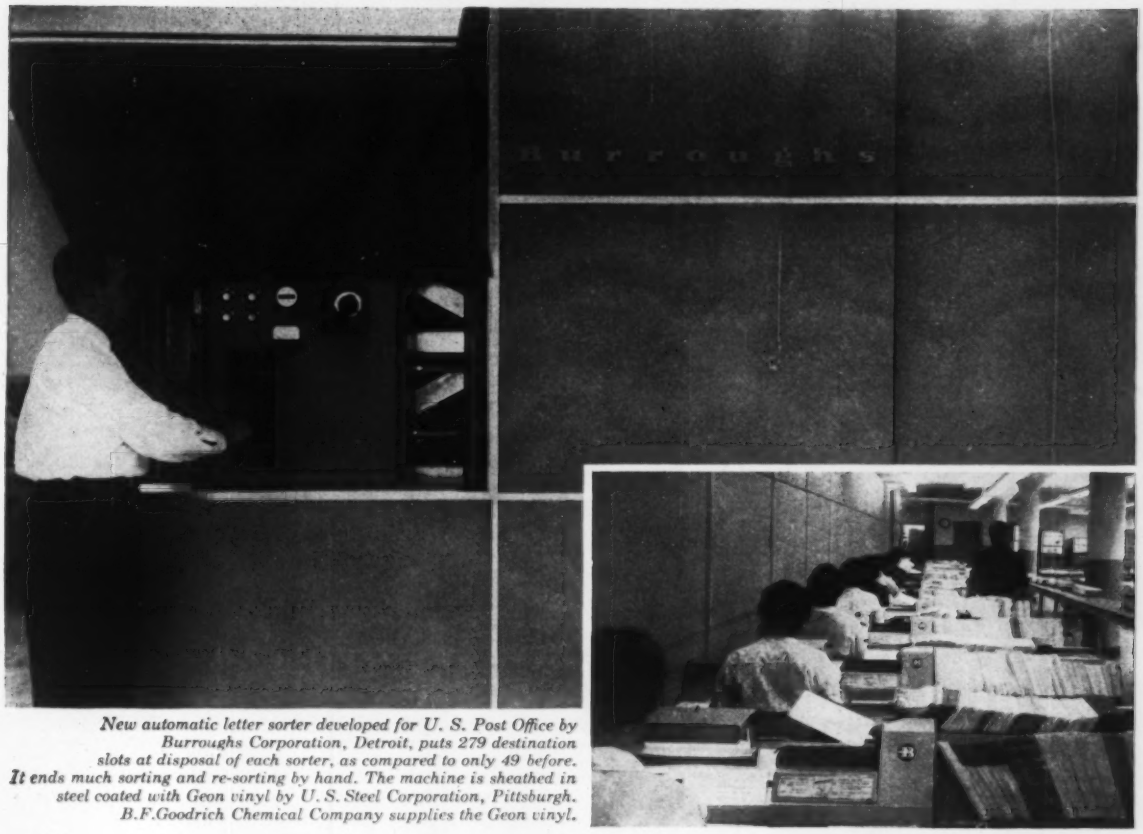
Another new development using

B.F.Goodrich Chemical *raw materials*



New automatic letter sorter developed for U. S. Post Office by Burroughs Corporation, Detroit, puts 279 destination slots at disposal of each sorter, as compared to only 49 before. It ends much sorting and re-sorting by hand. The machine is sheathed in steel coated with Geon vinyl by U. S. Steel Corporation, Pittsburgh. B.F.Goodrich Chemical Company supplies the Geon vinyl.

U.S. Mail sorting goes automatic

with new machine sheathed in steel coated with Geon vinyl

This new automatic mail sorter converts the age-old "peek and poke" hand method of sorting letters by destination to a smooth, 43,000 letters-per-hour sorting by machine. 78 feet long and 10 feet high, the machine is sheathed with a versatile new combination—steel coated with Geon vinyl.

The Geon coating provides a soft, pleasant look and feel. It can be washed. It won't scuff or stain. The color is permanent and the coating protects the steel against both wear and corrosion.

Geon-coated metals can be formed, bent, even projection-welded without damage to coatings. Products can be made to match the color combination or texture of almost any material.

Geon coatings also offer superior abrasion, electrical and chemical protection for the metal. It's another example of the way that versatile Geon is improving products and opening new markets. For more information, write Dept. GV-4, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

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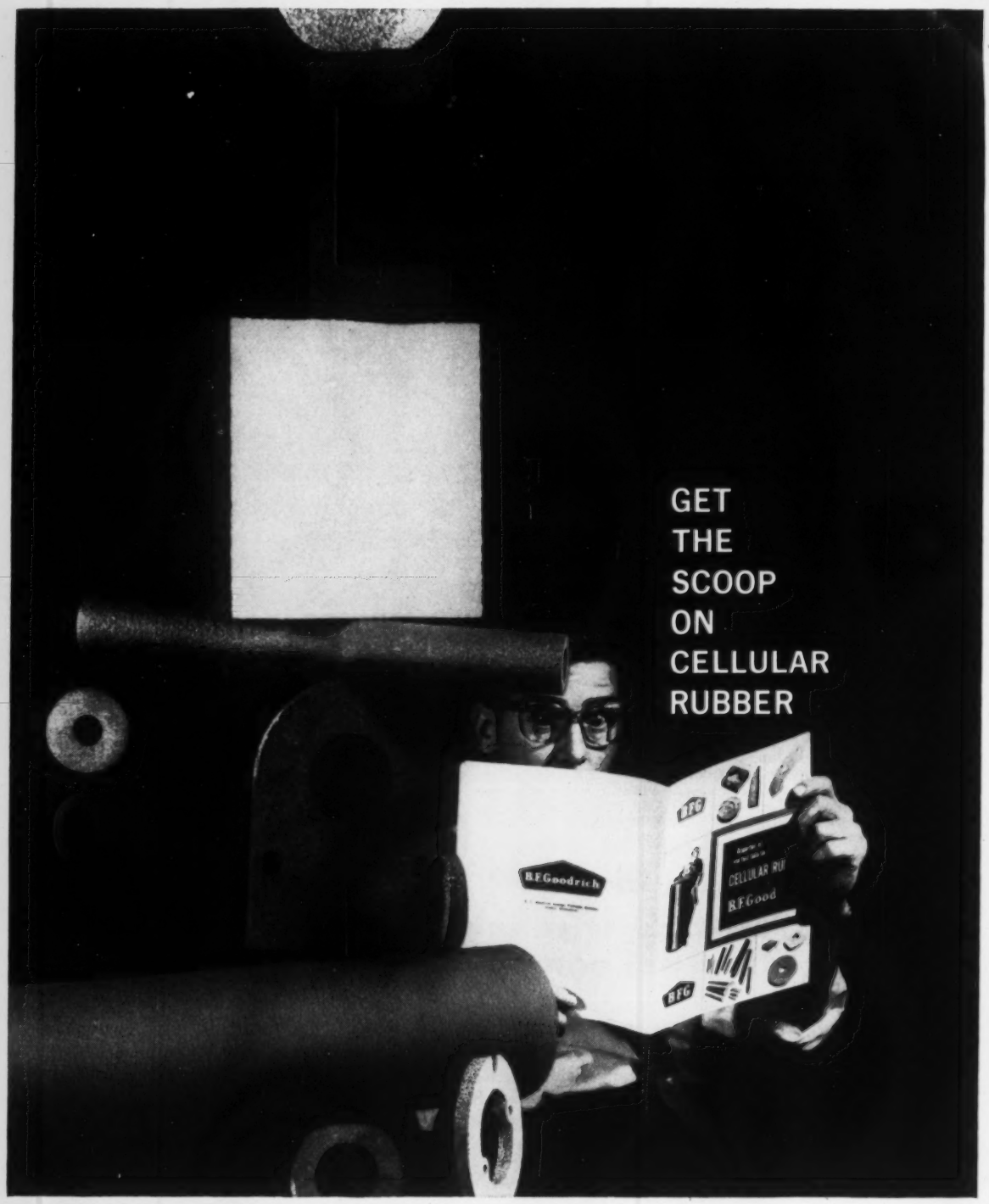

This 28-page B.F.Goodrich booklet is filled with information on properties, test data on BFG cellular rubber. Tells how to use this versatile material for insulation, sealing, cushioning, flotation, shock absorption, vibration dampening. Send request on your company letterhead. The B.F.Goodrich Company, 121 Derby Place, Shelton, Connecticut.

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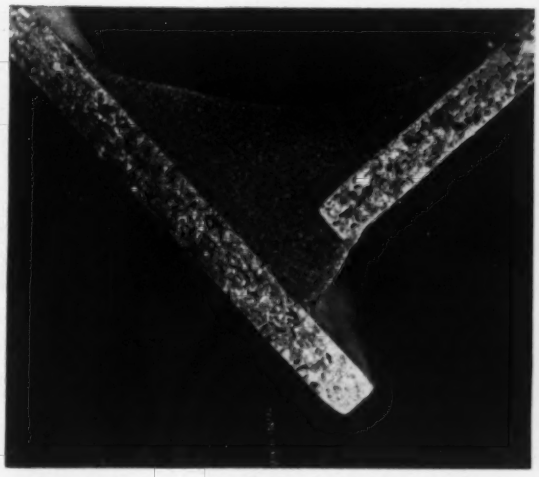
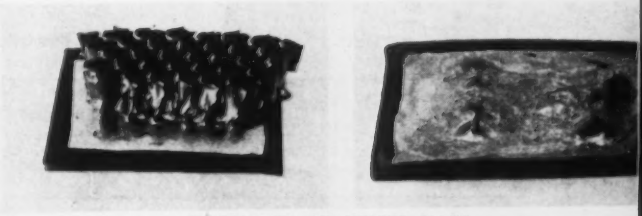
New Brazing Alloys Bridge Wide Gaps

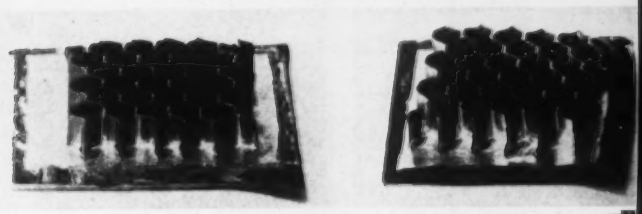
by **C. R. Benson,** *Metallurgical Products Dept., General Electric Co.*



***Joint brazed** with wide-gap alloy. (Enlarged about 12 times.)*



BRAZED WITH AIR MELTED ALLOY



BRAZED WITH WIDE-GAP, VACUUM MELTED ALLOY

***Much less erosion** occurs with wide-gap alloys. These pieces were held at 2150 F for 30 min.*

■ A series of vacuum melted brazing alloys, capable of bridging clearances of 1/16 in., has been made commercially available by the Metallurgical Products Dept., General Electric Co., Detroit, Mich. Composition and properties of the alloys cannot be released at this time.

How the alloys work—Wide-gap alloys are a mixture of two metal powders, one of which has a lower melting point than the other. When brazing temperatures are properly controlled, one powder melts and the other does not. The metal powder with the higher melting point is wettable by the fluid metal and acts somewhat like the aggregates in concrete. The two powders act in conjunction to fill the gap.

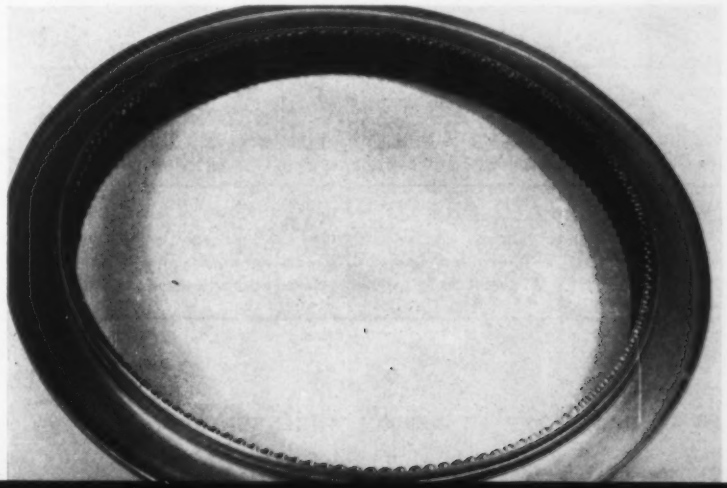
Use of the alloys eliminates the machining necessary to produce the usual 0.003-in. clearance specified in normal brazing operations. Because of the wide gap permissible, the alloys are expected to extend brazing techniques to jet engine, airframe and missile structures where welding is now used extensively.

Some advantages—Since the wide-gap alloys are produced by vacuum melting, contamination is reduced to a minimum. In particular, the lower gas content is desirable in vacuum brazing applications. The alloys also exhibit decreased erosion characteristics —an advantage when brazing thin sheet metal and honeycomb structures.

For more information, circle No. 600

***Rear frame** of 75-in. dia fan fabricated from 0.020-in. Inconel X sheet. More than 700 joints were brazed simultaneously.*

***J93 turbine shroud** of Hastelloy C with Inconel X honeycomb brazed-in using wide-gap alloy.*



ASTM Changes Gray Iron Spec to Include Section Size

Revision of A48 makes it easier to specify gray iron castings realistically.

TABLE 1—TENSILE STRENGTH REQUIREMENTS FOR GRAY CAST IRONS
(Separately Cast Test Bars)

Class ↓	Minimum Tensile Strength, psi			
	Test Bar A, 0.88 In. Dia[a]	Test Bar B, 1.2 In. Dia[a]	Test Bar C, 2.0 In. Dia[a]	Test Bar S (size as agreed upon)
20 A	20,000	20,000	20,000	20,000
20 B				
20 C				
20 S				
25 A	25,000	25,000	25,000	25,000
25 B				
25 C				
25 S				
30 A	30,000	30,000	30,000	30,000
30 B				
30 C				
30 S				
35 A	35,000	35,000	35,000	35,000
35 B				
35 C				
35 S				
40 A	40,000	40,000	40,000	40,000
40 B				
40 C				
40 S				
45 A	45,000	45,000	45,000	45,000
45 B				
45 C				
45 S				
50 A	50,000	50,000	50,000	50,000
50 B				
50 C				
50 S				
60 A	60,000	60,000	60,000	60,000
60 B				
60 C				
60 S				

[a]Approximate diameter as cast.

TABLE 2—DIAMETERS AND LENGTHS OF CAST TEST BARS

Test Bar ↓	As-Cast Diameter, in. (D)			Length, in. (L)	
	Nominal (mid-length)	Minimum (mid-length)	Maximum (top)	Minimum (specified)	Maximum (recommended)
A	0.88	0.85	0.90	5.0	6.0
B	1.20	1.14	1.26	6.0	9.0
C	2.0	1.90	2.1	7.0	10.0
S	All dimensions by agreement between manufacturer and purchaser				

■ One of the chief problems of the designer who uses a casting has always been how to deal with section size. It is well-known that, as section size increases, mechanical properties are adversely affected. A recent M/DE article (Feb '60, p 100) shows quantitatively the effect of section size on mechanical properties.

Until now, casting specifications have been one-dimensional statements which did not take this factor into account.

In its 1960 annual meeting, however, the American Society for Testing Materials approved a revision of the basic specification for gray iron, A48, in order to better define the relationship between section size and tensile strength. The revision also spells out how the tensile test bar is to be cast.

Using the newly adopted specification, the design engineer can, as before, require minimum tensile strengths ranging from 20,000 to 60,000 psi. However, each class of gray iron (20, 30, 40, etc.) has now been broken down into four subclasses—represented by a cast test bar of different diameter—which takes the effect of section size into account. As-cast diameters of test bars A, B and C are approximately 0.75 in., 1.25 in. and 1.875 in., respectively. (Test section diameters of the bars, in the same order, are 0.5 in., 0.75 in. and 1.25 in.) Table 1 presents the new tensile requirements of ASTM A48.

Both the supplier and the user of castings can now reach agreement on the required properties of castings with a minimum of negotiation. ASTM has introduced the "S" class of castings into the specification to allow both parties room to negotiate differences that might arise.

Test bars

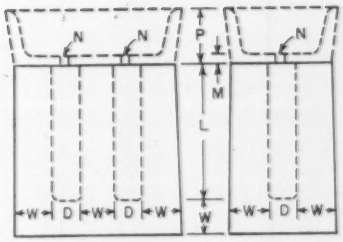
Test bars, as before, are separate castings poured from the same iron as the castings they represent. Dimensions of the test bars are given in Table 2. Recommended design for the test bar mold is shown in the accompanying drawing.

Although more than one test bar can be poured in a single mold, each bar must be surrounded by a thickness of sand which is not less than 1.5 times the bar diameter. In addition, the bars must be cast in dried or baked molds made mainly of an aggregate of siliceous sand with appropriate binders. Average grain size of the sand must be approximately that of the sand in which the castings are poured.

Thermal treatments the same as in the previous revision, the test bars must be treated in the same manner as the casting itself. Shakeout procedures, annealing, stress relieving, etc. are performed the same as with full size castings. Test bars are heat treated adjacent to the castings they represent.

Transverse test dropped

Prior versions of ASTM A48 included a transverse test as an optional method of qualification. This test has been removed from the newly revised A48 and should be conducted according to "Method of Transverse Testing of Grey Iron," ASTM Specification A438-60T. When a transverse test is specifically authorized as a basis for acceptance, minimum test values must be agreed upon in writing by the manufacturer and purchaser.



Recommended mold design *and dimensions for separately cast cylindrical gray iron test bars. Among the requirements: mold material must be an aggregate of dry siliceous sand; the bars must be poured vertically; and dimension W must not be less than 1.5 D. Dimensions L and D are presented in Table 2. Design of pouring cup is optional. Two test bars may be cast at once. Suggested dimensions are: P = 2 in., N = 5/16 in. dia, and M = 1.5 N.*

Experimental parts *coated with FEP fluorocarbon resin by fluidized bed process are pin fastener (left) and ball-valve components (right).*

FEP Fluorocarbon Coatings Now Applied by Fluidized Bed Process

■ FEP fluorocarbon resins have been added to the growing list of plastics that can be applied by the fluidized bed process (see "Fluidized Bed: Heavy Coatings in One Dip," M/DE, Feb '60, p 91).

The developer of the resins, E. I. du Pont de Nemours & Co., Inc., Polychemicals Dept., Wilmington 98, Del., says that in addition to having high corrosion resistance the coatings resist high temperatures and provide a transparent, smooth, nonsticking surface. These properties are expected to be useful in such applications as pump impellers, valves, rotors and other motor hardware, filter plates, pump heads, ball bearings, and irregularly shaped mechanical components.

Typical properties

Sample parts coated with 10 mils of FEP powdered resin have been immersed in both 2% and 0.1% concentrations of sodium hydroxide, and nitric, sulfuric and hydrochloric acids, as well as in a 4% sodium chloride solution and in tap water. All of the coatings remained impermeable after 30 days exposure at room temperature and 30 days exposure at 120 F.

Similarly, parts suspended 48

hr in a 1% sodium sulfate solution showed a resistance of 750,000 ohms after electrical tests of coating durability. In contrast, conventional organic coatings show only 10,000 to 15,000 ohms under the same conditions.

How they are applied

Before applying FEP coatings all surfaces are pretreated to assure adhesion and retention of film properties. Surfaces are first sandblasted and then solvent cleaned to remove grease and dirt. Further improvement in adhesion can be obtained by chromate treatment or oxidation etching. Also, significant improvements in the bond can be obtained by spraying on a special 1-mil-thick green primer.

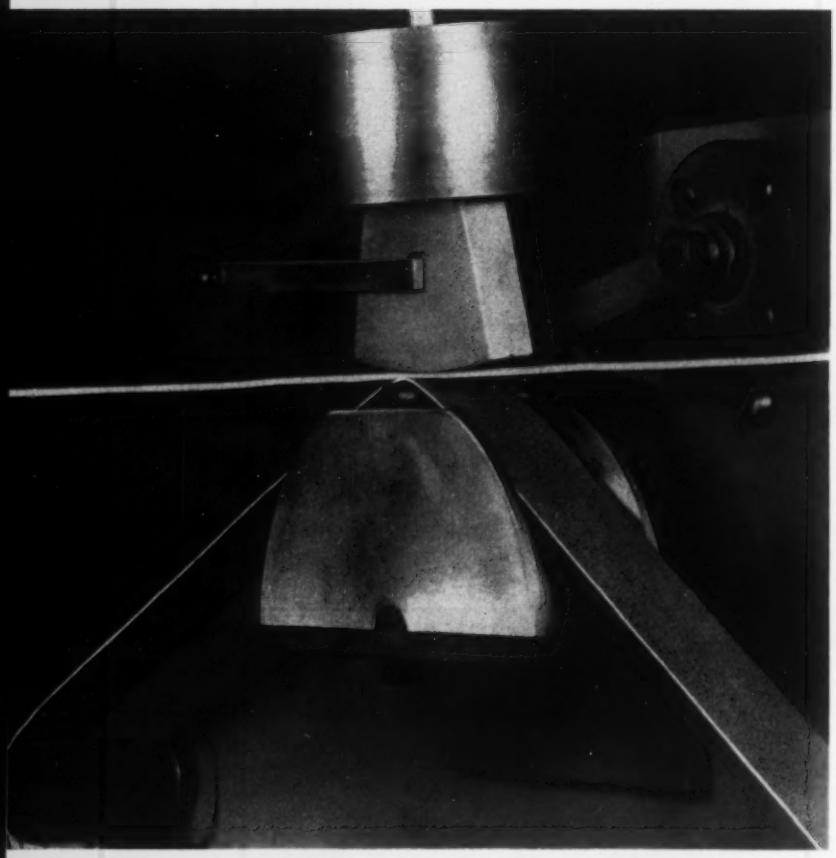
Prior to dipping in the fluidized bed of FEP powders, parts are oven-heated to a surface temperature of 650 F. This temperature is sufficient for thick parts that retain heat well; thin parts require a higher temperature.

After a 1 to 2-sec dip in the fluidized bed, parts are blasted with low pressure air to remove excess powder and are then returned to the oven for 20 min of additional heating to fuse the resin particles into a continuous 2-mil film. Additional dips and oven heating are required to build up an 8-mil film which is considered to be the minimum thickness for adequate corrosion resistance. Ordinarily, 1½ to 2½ mils are picked up on each dip after the initial one.

Maximum permissible coating thickness has been found to range from 15 to 17 mils. Above these limits the coatings tend to blister and sag.

For more information, circle No. 602

New Fluorocarbon Wire Insulation Resists Abrasion, Cut-Through



***Abrasion test** consists of pulling abrasive cloth tape across insulation under specified load. Results are expressed in inches of tape required to wear through the insulation.*

■ Orientation of the ceramic fiber reinforcement is the key to the superior resistance to abrasion and cut-through of a new TFE-fluorocarbon (Du Pont's Teflon) wire insulation called AR. Developed by W. L. Gore & Assoc., Inc., Newark, Del., the new insulation is said to have about 90% of the fibrous reinforcement oriented parallel to the surface, as opposed to about 50% orientation in random reinforced types.

The mineral fibers are about 1 μ in dia, and 500-1000 μ in length. Quantity of fibers is sufficient to improve abrasion resistance, but not to significantly impair the good dielectric properties of the resin. For example, as compared with values for virgin TFE of 2.0-2.05 for dielectric constant, 0.0003 for dissipation factor, and 10^{15} ohm-cm for volume resistivity, the new insulation has a dielectric constant of 2.1-2.15, dissipation factor of 0.001, and volume resistivity of 10^{13} ohm-cm.

Data indicate improvement

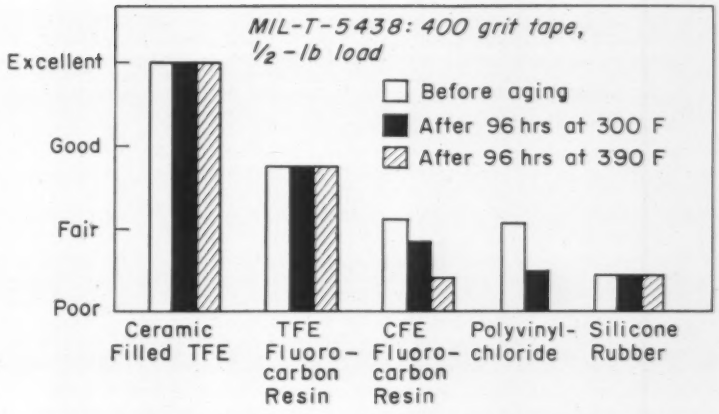
Several test results are reported by Gore on abrasion and cut-through resistance of the new insulation:

1. Under NAS 703 test procedure, abrasion resistance rating

of the new insulation is 52 in., compared with 35 in. for standard TFE insulation. NAS 703 specifies a minimum rating of 48 in. Tests were made on wires with 22-E-type conductors with insulation forming an overall 0.050 in. o.d. Load was ½ lb on 400 grit abrasive cloth, using MIL-T-5438 apparatus.

2. Under MIL-W-7139A (for aircraft wiring) abrasion resistance tests, AR wire insulation produces a rating of 35 in., exceeding the minimum specification rating of 22 in. According to Gore, standard TFE insulation is hard put to meet this minimum requirement. Tests were made on AWG 20 conductor and a total of 0.030 in. insulation consisting of 0.005 in. primary TFE insulation and 0.025 in. AR jacket. Test conditions included 4/0 grit abrasive cloth tape and 1-lb weight on 0.090 in. o.d. wire conforming to Designation RM-20.

3. Cut-through resistance was found to be about three times that of standard TFE insulation, as indicated by results of a non-standard cut-through test. AR insulated wire required an average of greater than 12 min to cut-through; of the 10 tests run, 50% were halted at 15 min where there was no indication of impending failure. Standard TFE insulated hookup wire averages 4-5 min. Tests were made on 22 E wire; weight was hung on 10-in. lever arm with sample placed on anvil 1 in. from fulcrum to multiply 500-gm load by 10 at the sample; measurements were in terms of time required for a 1/16 in. mandrel pressed at right angles to axis of wire to cut through the insulation and short the conductor.



Qualitative comparison *shows new ceramic fiber-reinforced fluorocarbon to be superior to several other types of wire insulation.*

An additional benefit of the reinforced composition, according to Gore, is improved retention of mechanical strength at higher temperatures (up to 620-750 F), for many hours, possible weeks.

New types of wire

Possibly the greatest significance of the new insulation is the potential for producing entirely new types of insulated wire. For example, according to the producers, reductions in the size of airframe wiring can be attained by using 5 mils of corona resistant TFE (see M/DE, Mar '60, p 9) and 10 mils of AR for a total of 15 mils, forming an EE type insulation. This would provide a reduction of 30 mils in o.d. with AWG 20 conductor, and thus a 30% reduction in space, and roughly 50% reduction in weight.

In comparison with standard MIL-W-7139 wire (TFE-glass-TFE), a combination of 10 mils of corona resistant TFE and 20 mils of AR is said to give greater corona-stress resistance, higher heat resistance, superior resistance to cut-through and abrasion, and much higher dielectric strength. It also exceeds requirements of the new MIL-W-27300 spec covering 572 F wire—yet its cost is about the same as that of standard 7139 wire.

For more information, circle No. 603

Single Crystals of Refractory Metals Now Available

■ Single crystals of refractory metals are now available in commercial quantities from Linde Co., Div. of Union Carbide Corp., 270 Park Ave., New York 17.

Crystals are produced by an arc fusion crystal growing process similar, in some respects, to the Verneuil flame fusion process used in Linde's commercial production of synthetic sapphire, star sapphire, etc. A primary advantage of the process is the fact that no container is required, thus minimizing contamination problems. In addition, by using an electric arc instead of combustion flames, the process can make use of a wider range of temperatures and atmospheres.

Properties of single crystals produced to date are given in Table 1 which appears at the top of the next page.

What are the advantages?

Gains made by using single crystals are:

1. They have much better ductility than polycrystalline materials.

TABLE 1—PROPERTIES OF SINGLE CRYSTALS OF REFRACTORY METALS AND COMPOUNDS

Material	Formula	Crystal Structure	Melting Point, F	Vickers Hardness (300-gm load)	Density (theor), gm/cu cm[a]
Tungsten	W	Body centered cubic	6098	67	19.259
Molybdenum	Mo	Body centered cubic	4757	192	10.2
Vanadium	V	Body centered cubic	3155	189	6.0
Columbium	Cb	Body centered cubic	4379	107	8.57
Tantalum	Ta	Body centered cubic	5425	119	16.6
Titanium Monoxide	$TiO_{1.19}$	NaCl cubic	About 3200	1406	Unknown
Titanium Sesquioxide	Ti_2O_3	Trigonal (corundum)	Unknown	1351	Unknown
Titanium Carbide	$TiC_{0.94}$ (19% C)	NaCl cubic	5882	3230	4.93
Molybdenum Disilicide	$MoSi_2$	Tetragonal	3686	1097	6.24

[a]Density of the single crystal material has been measured and the accuracy of measurement (±0.02 gm/cu cm) could not distinguish between the real and the theoretical density.

TABLE 2—AVAILABILITY OF 'AS GROWN' SINGLE CRYSTALS

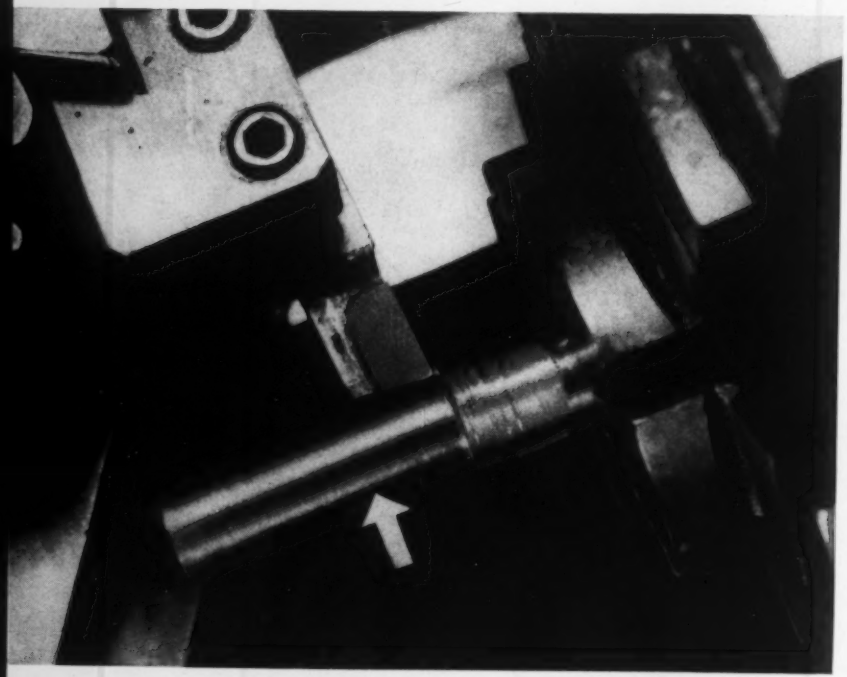
Material	Largest Dia, in.	Max Length, in.
Tungsten	⅝	12
Molybdenum	¾	12
Vanadium	¾	12
Columbium	⅜	12
Tantalum	⅝	12
Titanium Monoxide	⅜	2
Titanium Sesquioxide	¼	½
Titanium Carbide	⅜	¾
Molybdenum Disilicide	¼	½

2. They contain relatively small amounts of impurities, thus minimizing brittleness caused by oxide inclusions.

3. They can be worked and formed at temperatures significantly lower than those normally associated with the refractory metals. For example, threads can be tapped into bolts made from a tungsten single crystal without cracking the metal.

4. They are essentially nonporous (see densities in Table 1).

5. Standard metalworking processes, such as swaging, can be performed on them.



***Boule of tungsten** single crystal being machined at room temperature.*

Crystal orientation

In the case of the metal crystals, the most likely orientation is with the <100> direction making an angle of 30 deg with the cylinder axis. However, metal crystals can also be made with the <100>, <110> or <111> crystallographic directions parallel to the cylinder axis within ±5 deg.

A certain amount of lineage, or areas misoriented with respect to each other by not more than 5 deg, can be expected in each crystal. Tungsten crystals ¼ in. or less in dia can be grown without lineage, and preliminary investigation indicates that this condition will hold for other metal crystals.

Applying single crystals

The new single crystals may lend themselves to the solution of a variety of problems in high temperature electronics, and in cases where wear, corrosion and high temperatures are important design considerations.

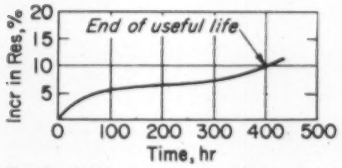
High purity, nonporous tungsten crystals may be applied as contact points in vacuum switches, lead-ins to vacuum equipment, and other applications where outgassing is a problem. Their low cold emission, resulting from their high purity, may lead to other electronic applications.

High temperature semiconductors may be fabricated from nonmetallic single crystals such as titantium diboride. Several of the oxide crystals have interesting conductivity characteristics. Titanium diboride combines conductivity in an unusual way with hardness and corrosion resistance.

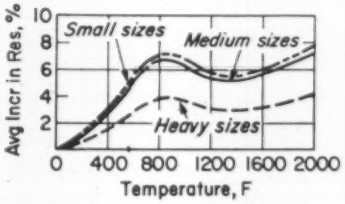
Availability

Single crystals are being manufactured by Linde in production quantities. Made as boules, or "as grown" shapes, the crystals can be obtained in that form or in fabricated shapes that include rods, disks, etc. with ground or polished surfaces. Sizes of currently available boules are shown in Table 2.

For more information, circle No. 604



Typical life curve *for Chromel AA based on ASTM life test at 2150 F.*



Temperature - resistance *curves shows increase in resistance of Chromel AA wires when heated.*

TABLE 1—RESISTANCE TO CARBURIZATION[a]

Alloy	Carbon Pickup, %
Chromel AA	0.46
80 Ni–20 Cr	0.64
35 Ni–20 Cr, bal Fe	1.70

[a]Exposure: 80 hr at 2150 F in atmosphere with 1% carbon potential at 55 F dew point.

New Alloy for 2150 F Heating Elements

■ Recently announced by Hoskins Mfg. Corp., 4445 Lawton Ave., Detroit 8, Mich., Cromel AA is a modified 80% nickel–20% chromium alloy with small additions of iron, silicon, cobalt, manganese and columbium. The alloy has high resistance to carbon pickup at all temperatures (see Table 1) and, in addition, resists corrosion at elevated temperatures in reducing atmospheres.

Other features of the alloy: resistance to attack by sulfur, chlorine and other harmful contaminants often present in controlled atmospheres; and resistance to "green rot," the preferential intergranular oxidation of chromium that is frequently encountered in the temperature range 1500 to 1800 F.

Mechanical and physical properties are given in Tables 2 and 3. The graphs give typical life and temperature resistance curves.

For more information, circle No. 605

TABLE 2—MECHANICAL PROPERTIES OF CHROMEL AA

Temp, F	Ten Str, 1000 psi[a]	Elong, %	Rupture Stress (100 hr), 1000 psi	Creep Stress (1%/1000 hr), 1000 psi
68	130	30	—	—
1200	95	21	—	13
1500	37	18	6	4
1700	23	22	4.7	1.2
1900	13	15	2.5	—

[a]Tensile strength and elongation determined with 0.0285-in. dia annealed wire; all other tests performed on 0.064-in. dia annealed wire.

TABLE 3—PHYSICAL PROPERTIES OF CHROMEL AA

Melting Point, F	2535
Maximum Continuous Service Temp, F	2150
Resistivity (68 F), ohms/cmf	
Wire	700
Strip	550
Temperature Coefficient (−55 to +150 C), ppm/°C	+110
Thermal Conductivity (100 C), w/cm/°C	0.13

Cost of High Frequency Transistors Cut

by new post-alloy diffusion process

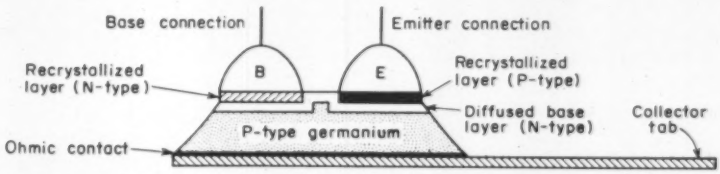
■ Many new applications for high frequency transistors can be expected as the result of a development breakthrough which improves production and lowers cost. Developed by the Phillips Co. of Holland, the new transistors will shortly be mass-produced by Amperex Electronic Corp., a Subsidiary of North American Phillips Co.

Conventional techniques have drawbacks

The VHF transistor breakthrough is made possible by a new post alloy diffusion process which combines the best features of currently used alloy and diffusion processes, without their drawbacks.

The conventional alloy process is limited in manufacturing transistors with an average cutoff above 20 mc. In this process the collector and emitter elements are fused or alloyed to the base. For this to be successfully accomplished the base must be relatively thick and the thickness very accurately controlled so that during fusion the collector and emitter elements do not flow through the base and short the transistor. This relatively thick base increases transit time, thus precluding any usable response above 20 mc.

In the diffusion process the base is formed on the collector by gaseous diffusion in a high temperature oven. Very thin bases can be manufactured by this method with low transit



Process details *are shown in this schematic cutaway of transistor during manufacture.*

time and very high cut-off frequencies. However, the problem in this process lies in attaching the emitter junction and base lead.

Alloying and diffusion combined in new process

Key to the success of the new post alloy diffusion process is that alloying and diffusion occur simultaneously. As shown in the accompanying figure, the transistor is built up on a piece of P-type germanium. Two small pellets are placed on the germanium. Pellet B, the base pellet, contains only an N-type impurity. Pellet E, the emitter pellet, contains a P-type and an N-type impurity.

When this assembly is heated, the germanium dissolves into the pellets until saturation is reached, and the pellet impurities dissolve into the solid germanium. However, the P-type impurity in pellet E has such a low diffusion constant that for practical purposes it does not penetrate into the germanium. The N-type impurity in pellets E and B has a much greater diffusion constant and readily penetrates into the solid germanium to form a diffused N-type layer underneath the pellets.

When the assembly is cooled a layer of germanium recrystallizes from the pellets as in the normal alloy technique. The recrystallized layer of pellet E contains many atoms of the P-type impurity and is, therefore, a P-type germanium layer. The germanium layer recrystallized from pellet B is, of course, the N-type because there are not other impurities in the pellet.

Connections are made to the germanium and the pellets and a "mesa-like" P-N-P transistor is obtained. The original P-type germanium is the collector, pellet B the base, and pellet E the emitter.

Process opens up new uses

The new process is important because it makes it possible to mass-produce transistors with a base layer of a few ten-thousandths of an inch with a very short transit time and high cut-off frequency. Because of the high yield the transistors can be supplied at low prices.

Typical uses now feasible for the high frequency transistors include: RF and IF amplifiers for FM receivers; mixers, oscillators and RF IF amplifiers for mobile radio equipment, car radios and short wave receivers; and broadband amplifiers in instrumentation and industrial applications.

For more information, circle No. 606

Low-Loss Laminates for High Temperature Electrical Structures

A new resin used in filament wound or fabric-reinforced structures, such as radomes, provides good retention of electrical and mechanical properties in the 500-600 F range.

by S. A. Miller, *Chief R&D Engineer, and* **J. S. Carter,** *Senior R&D Engineer, Brunswick Corp.*

■ A new resin system for reinforced plastics structures provides extremely low and consistent loss and dielectric constant values at temperatures up to 600 F, and over a wide frequency range. With increasing temperatures, dielectric constant decreases slightly, while loss tangent remains constant. The material appears suitable for extended use at 500-550 F and short-time use at 600 F.

Physical and mechanical properties of laminates made with the resin system are relatively good. Although initial strengths are lower than those of many conventional laminates, percentage loss in strength with increasing temperatures is less than that of most laminate systems.

Reinforced plastics structures produced with the new resin system, designated JC-1571, are available commercially on a custom basis from Brunswick. Although specific details on the nature of the resin are proprietary, in general terms the resin is a modified vinyl material. Processing and fabrication characteristics of laminates are comparable to those of laminates made with conventional styrene-polyester resins. Cost is slightly higher than that of styrene-polyesters.

Electrical properties

Table 1 shows dielectric constant and loss values for the material in various forms at a frequency of 9.375 kmc. The relatively high values for the filament wound specimen are due to the extremely high glass content (87% by weight).

Fig 1 shows effects of increasing temperature on loss and dielectric constant of unidirectional filament wound specimens (13%

by weight resin). Note that loss factor remains constant with temperature, except for one value measured as temperatures were decreased. This increase in loss with descending temperature was probably due to small spaces produced between the specimen and the waveguide as a result of thermal contraction.

Dielectric constant decreased both with increasing and decreasing temperatures.

Fig 2 shows effects of frequency on dielectric constant and loss of unfilled cast resin specimens. Loss tangent fluctuated slightly with frequency but not appreciably.

The material offers distinct advantages for such applications as electromagnetic windows exposed to temperatures in the 500-600 F range. Table 2 compares electrical characteristics of JC-1571 with those of TAC polyesters, silicones, phenolic and phenyl silane resins. Variations of insertion phase delay with temperature is greatly minimized, and, with some modification of the ratio of constituents, the material may even be self-correcting.

Thermal properties

Thermal coefficient of linear expansion for filament wound laminates is a low 2.25×10^{-6} per °F from room temperature to 500 F. Above 500 F, the laminate begins to deteriorate and expansion decreases with time until it becomes negative.

TABLE 1—ELECTRICAL PROPERTIES OF JC-1571
(Measured at 9.375 Kmc)

Specimen	Resin Content, %	Dielec Const	Loss Tangent
Liquid Resin	100	2.252	0.0032
Unfilled Casting			
Dry	100	2.379	0.0032
Wet[a]	100	2.378	0.0032
Fabric-Reinforced Laminates			
181 Cloth	30	3.680	<0.0080
181 Cloth with Silicone[b]	30	3.53	<0.008
High Silica Fabric[c]	23	2.729	0.0031
Filament Wound	13	4.04	<0.010

[a]24-hr water immersion.
[b]Resin blend of JC-1571 and Dow Corning 7146 silicone.
[c]H. I. Thompson Fiber Glass Co.'s Refrasil.

TABLE 2—COMPARATIVE ELECTRICAL PROPERTIES[a]

Material	Test Temp, F	Dielectric Constant (at 9.375 kmc)	ϕ (calculated electrical thickness), deg[b]	$\Delta\phi$[c]	$\Delta\phi/\phi \times 100$, %
TAC-Polyester					
Resin A	600	4.34	185	>+5	2.7
Resin B	690	4.21	186	>+6	3.3
Silicone					
Resin A	560	4.91	186	>+6	3.3
Resin B	560	4.87	187	>+7	3.9
Phenolic	500	5.52	192	>+12	6.6
Phenyl Silane	520	5.02	192	+12	6.6
JC-1571	600	3.96	179	<−1	0.5

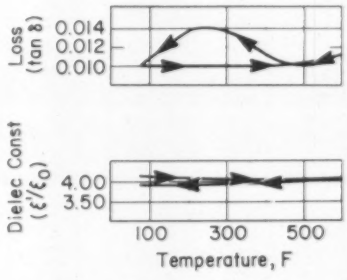
[a]Filament wound unidirectional specimens.
[b]$\phi = (360\ d/\lambda)\ (\epsilon'/\epsilon_0 - \sin^2\theta)^{1/2}$; where $\theta = 60$ deg (d = thickness); — = when errors occur.
[c]$\Delta\phi$ neglects additive effect of thermal expansion, except for that on JC-1571, which is so small it can be neglected.

Specific heat is 0.237 Btu per lb between room temperature and 800 F.

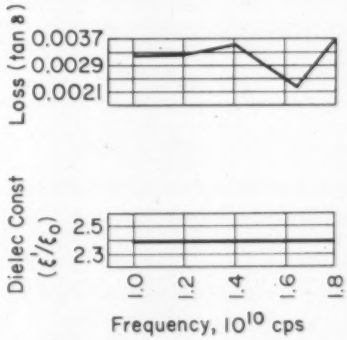
Thermal conductivity is fairly linear from room temperature to 800 F, ranging from a low of 0.695 Btu/hr/sq ft/°F/in. at 167 F, to a high of 1.668 at 800 F.

Mechanical properties

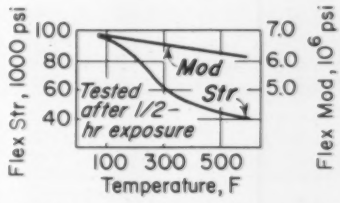
Two types of laminates were evaluated for mechanical strength: unidirectional filament wound specimens, and conventional 181 glass cloth-reinforced specimens



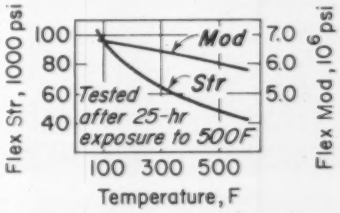
1—*Loss and dielectric constant of unidirectionally reinforced specimens vs increasing and decreasing temperatures.*



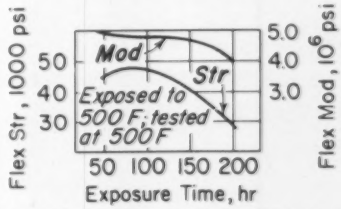
2—*Effect of frequency on loss and dielectric constant of unfilled casting.*



3—*Effects of ½-hr exposure at increasing temperatures on flexural strength and modulus of unidirectional, filament wound specimens.*



4—*Effects of 25-hr exposure to 500 F prior to testing at indicated temperatures.*



5—*Effects of aging at 500 F on filament wound specimens. Tests were conducted at 500 F.*

produced by bag molding.

Unidirectional reinforced laminates—Laminates had a final resin content of 13% by weight, and were tested by both envelope (both sides) heating and by one side heating.

Fig 3, 4 and 5 show how envelope heating the specimens for varying times effects flexural strength and modulus. Note that flexural modulus, in particular, is relatively slightly affected. For example, ½ hr at 600 F only reduced flexural modulus from initial values of about 6.8×10^6 to 6.08×10^6. As shown in Fig 5, laminates retained high modulus values after 200 hr aging at 500 F.

Effects of one-side heating at various heat inputs on flexural strength and modulus are shown in Fig 6. At 5 and 15 Btu/sq ft/sec heat flux, flexural modulus is retained very well with time; the high 30 Btu/sq ft/sec flux begins to degrade the laminate rapidly after 2 min.

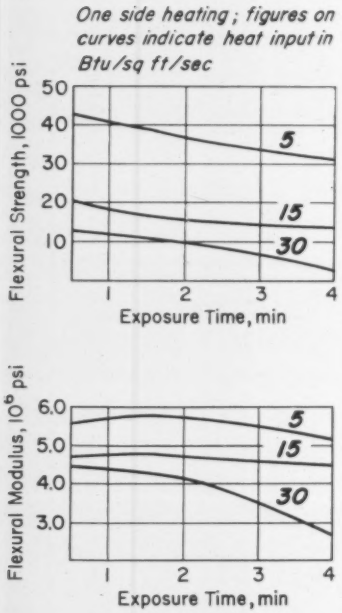
181 cloth laminates—Bag molded conventional laminates were tested by envelope heating only.

Fig 7 shows the relatively rapid drop off in flexural strength of the laminates on initial heating. However, aging at 500 F (Fig 8) and 550 F (Fig 9) substantially improves flexural strengths (probably due to further crosslinking) before strengths drop off on continued exposure. Fig 8, 9 and 10 show flexural modulus to be only slightly affected by heat.

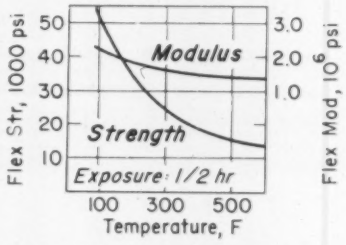
Fig 10 shows the good retention of tensile and shear strengths of 181 laminates; compressive strength, however, falls off appreciably. Further postcure should improve these properties considerably.

Acknowledgment

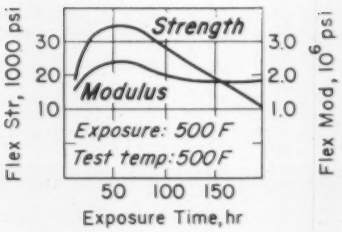
Thermal properties were measured by Southern Research Institute, Birmingham, Ala. Elevated temperature electrical measurements were conducted by Aero Geo Astro, Alexandria, Va.



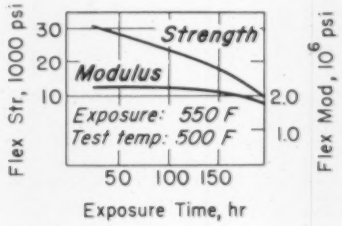
6—*Effects of one-side heating of filament wound specimens at three different heat fluxes on flexural strength (top) and modulus.*



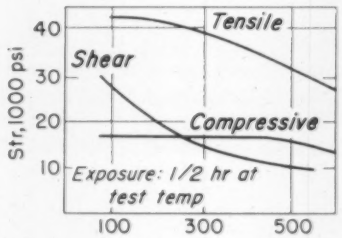
7—*Effect of ½-hr exposure at increasing temperatures on flexural strength and modulus of 181-fabric-reinforced laminates.*



8—*Effect of aging at 500 F on 181-fabric laminates.*



9—*Effect of aging at 550 F on 181-fabric laminates.*



10—*Effects of temperature on tensile, Johnson Shear, and compressive strengths of 181-fabric laminates.*

For more information, turn to Reader Service card, circle No. 607

MORE WHAT'S NEW IN MATERIALS

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The largest production-line reinforced plastic power cruiser!

Here's why the Hatteras Yacht Company picks POLYLITE polyester resins for these beautiful boats.

POLYLITE has already demonstrated its outstanding performance in thousands of seaworthy boats – large and small. It has become the preferred construction material among manufacturers of quality glass-reinforced plastic boats. POLYLITE helps to insure that the hull of the unique, new Hatteras 41 stays strong, sleek, colorful and virtually maintenance-free.

The use of POLYLITE in this boat marks the first serious entry of reinforced plastic construction in the large power cruiser field. When planning the "41," its High Point, North Carolina, builder turned to Reichhold as plastic materials experts. For almost a year prior to its actual production – during the design and construction stages – RCI worked closely with the Hatteras people.

Boatbuilders everywhere have come to expect this kind of performance from RCI. They have learned that they get top-quality plastic materials, *plus* technical assistance on specific applications.

Such assurance of dependability and satisfaction has made RCI POLYLITE polyester resins the choice of boat manufacturers from coast to coast and around the world.

Creative Chemistry... Your Partner in Progress

RCI

REICHHOLD

REICHHOLD CHEMICALS, INC., RCI BUILDING, WHITE PLAINS, N.Y.

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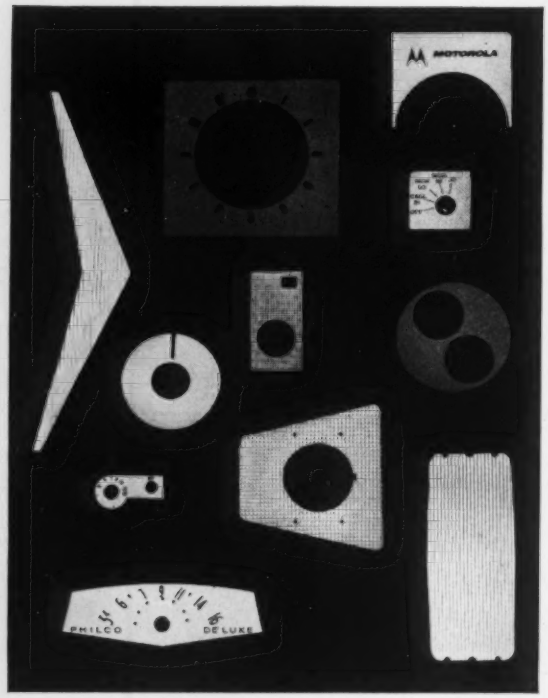
Replace Metal Parts Like These...



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First, it is an ideal replacement for metal . . . and it costs less. It has excellent abrasive and shock resistance, won't tarnish or turn dull. It is available in a wide range of beautiful metallic finishes in a variety of embossed patterns. Your printer or converter can easily print it any color, hot stamp it if desired, die cut it any size or shape.

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Investigate these two cost-saving advantages. Write today for samples and prices. Dept. T-8.

*Mylar is a DuPont Polyester Film

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Fasson Products

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Makers of Self-Adhesive Papers • Foils • Films • For Converters

For more information, turn to Reader Service card, circle No. 380

Some cold facts

To the Editor:

On p 161, line 5 of your June '60 issue, you say that "Ice can be thought of as a metal that melts at 32 F." Would you also say that zirconium oxide can be thought of as a metal that melts at 4900 F?

My point is that the oxide of the metal hydrogen is no more metallic than the oxide of the metal silicon. Pure ice is an oxide, an insulator, brittle and transparent, as are most oxides. Ice should therefore be thought of as a ceramic material which it more closely resembles. Dr. Kingery who worked on the ice research at MIT would undoubtedly agree with me.

As to the statement about ice's lack of usefulness, I dare you to convince someone imbibing a cold highball or other type of drink of this fact.

H. D. Root
Ceramics Section
Materials Engineering Dept.
Westinghouse Electric Corp.
Pittsburgh, Pa.

New welding processes

To the Editor:

The article "The New Welding Processes" (M/DE, Jan '60, p 105) has been of great help to me in preparing a speech on the subject of welding.

If possible, I would like to obtain samples of parts welded by such techniques as electron beam, ultrasonic, percussion, thermal compression, electroslag and friction.

J. R. Pence
Paradise Trailer Ct.
Gainesville, Fla.

We suggest contacting High Vacuum Equipment Corp. (electron beam), Aeroprojects, Inc. (ultrasonic), Precision Welder & Flexopress Co. (percussion), Bell Telephone Laboratories (thermal compression), and Arcos Corp. (electroslag).

News item on ceramics clarified

To the Editor:

We would like to clarify a news item appearing in your June '60 issue, p 5, line 1. Apparently the technical details of several different ceramics were confused.

The particular material described—a spodumene—has a thermal expansion coefficient of approximately 1.1×10^{-7} per °F over the temperature range 68 to 300 F. It is dense, does not outgas, and has been used *only* for precision microwave cavities. It can be fabricated by slip-casting or extruding.

The ceramic we are evaluating for use as ferrite supports is slip-cast fused silica, a commercial prod-

35 MILLION BEARINGS...

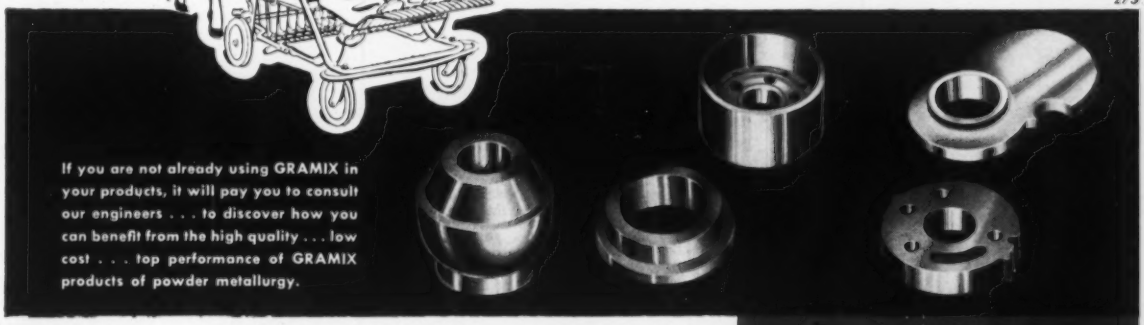
and every one has given perfect performance!

that's the record of GRAMIX® bearings in the famous TAYLOR-TOT® SLEEPER WALKER-STROLLER

Where there are youngsters, there are Taylor-Tots . . . and where there are these familiar sleeper walker-strollers there are GRAMIX bearings . . . in fact, 35 million to date have been shipped to the Frank F. Taylor Company of Cincinnati and have been accepted by their receiving inspection department without a single rejection. The strength, durability and resistance to wear of these GRAMIX bearings, two of which are used in each wheel, help give Taylor-Tot easier steering and handling. Even though Taylor-Tot strollers are run through snow, dirt and many times are left out in adverse weather, GRAMIX bearings provide the maximum in quietness, free running and long life.

GRAMIX is the ideal bearing material because it can be oil-impregnated for self-lubrication, requires no machining and is completely dependable.

273



If you are not already using GRAMIX in your products, it will pay you to consult our engineers . . . to discover how you can benefit from the high quality . . . low cost . . . top performance of GRAMIX products of powder metallurgy.

Write today for Engineering Bulletin No. 18, which covers design and metallurgical requirements and alloy selection of GRAMIX bearings. ▶

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DIVISION OF THE WICKES CORPORATION, SAGINAW 3, MICHIGAN

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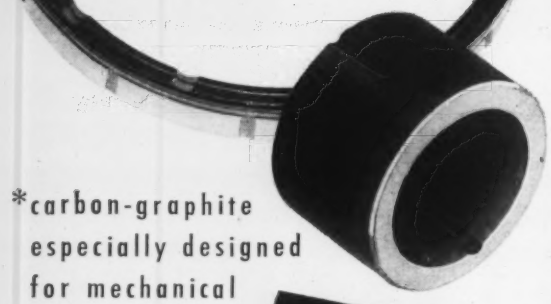
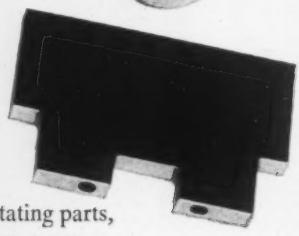
DO YOU HAVE A LUBRICATION PROBLEM ON...

SEAL RINGS
BLADES
BEARINGS?

WHY NOT TRY *PUREBON



*carbon-graphite especially designed for mechanical applications



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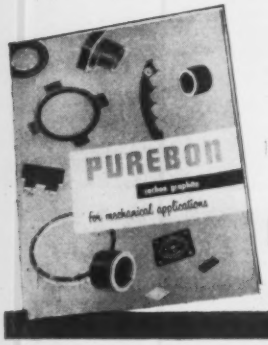


REQUEST BULLETIN NO. 60 OR SEE SWEET'S PRODUCT DESIGN FILE

PURE CARBON CO., INC.
448 HALL AVENUE
ST. MARYS, PENNSYLVANIA

For more information, turn to Reader Service card, circle No. 344

uct of Glasrock Products, Inc., Atlanta, Ga. It has a thermal expansion of 3.0×10^{-7} per °F over the temperature range 32 to 1800 F, as reported by the manufacturer.

The high thermal conductivity ceramic designed for backward wave oscillator tubes is a microwave attenuator material intended for use as a high power load or termination.

The above three materials are entirely different in composition and properties.

L. E. GATES
Advanced Structures Section
Components Div.
Hughes Aircraft Co.
Culver City, Calif.

Wide steel plates

To the Editor:

We would like to register a friendly but firm complaint regarding an item which appeared in the Prices & Supply section of M/DE's May '60 issue (p 27, line 6). The item states: "Steel plates in widths up to 210 in. will be rolling off a new plate mill early in 1962. Widest plates available now measure 160 in."

We take exception to the second sentence. Lukens Steel Co. installed a 206-in. mill back in 1918 and since then has regularly offered plate in widths up to 195 in. In special cases, plates have been rolled as wide as 202 in.

D. L. HUNGERFORD
Market Development Div.
Lukens Steel Co.
Coatesville, Pa.

Machinability of urethane elastomers

To the Editor:

We have read with interest your article on "Solid Urethane Elastomers" (M/DE, Oct '59, p 92). We would appreciate receiving any available information on the machinability of this material. Also, is the material available in stock quantities? If so, where can it be obtained?

R. J. CROSBY
Resident Engineer
USI Clearing Div. of
U. S. Industries, Inc.
Hamilton, Ohio

Machinability of solid urethane elastomers varies depending on hardness and type. For specific information, we suggest contacting Mobay Chemical Co., Pittsburgh, Pa., or E. I. du Pont de Nemours & Co., Inc., Elastomer Chemicals Dept., Wilmington, Del. There are no standard stock shapes of the material available.

WIN CASH—Each month $10 will be paid for the best letter written to an author (through us), an editor, or addressed to this column. We reserve the right to withhold awards.

What every designer should know about

High nickel alloy springs for corrosive environments

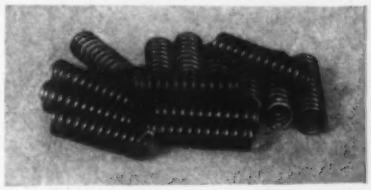
The highly corrosive petroleum products passing through this "christmas tree" valve practically dictate the use of high nickel alloy springs. They provide specific technical and economic advantages for valves, electrical components and other applications in corrosive environments such as chemicals, sea water, mine water or power plants.

Inconel* nickel-chromium alloy offers especially high resistance to stress-corrosion cracking or embrittlement by corrosive fluids at high temperatures. Inconel "X"* alloy, which is age-hardenable, resists relaxation under corrosive conditions at temperatures as high as 1200°F...remains ductile at –320°F or lower.

Versatile corrosion-resisting properties of Inconel and Inconel "X" alloys are based, generally, on their high Nickel content for resistance to reducing media; and on their chromium content for resistance to oxidizing conditions. Thus, Inconel and Inconel "X" alloys...

- **Are unaffected by most neutral and alkaline salt solutions...are among the few materials suitable for use with hot, strong magnesium chlorides.**
- **Are exceptionally resistant to hot fatty acids...alone or mixed...including stearic, oleic, linoleic and abietic.**
- **Are practically free from corrosion by distilled or fresh water...including the most corrosive of natural waters containing free carbon dioxide, iron compounds, chlorides or dissolved air.**
- **Are bright metals and retain their brightness indefinitely in most indoor locations.**

Helpful new Technical Bulletin T-35, "High Nickel Alloy Helical Springs," gives valuable design, fabricating and specifying data on springs of Inconel alloys and other corrosion-resisting high nickel alloys. On "K" Monel* and Duranickel*, for example ...for effective service with such corrosives as mineral and organic acids, alkalies, salts...potable and industrial waters...food products, organic compounds and oxidizing atmospheres at normal and elevated temperatures. Find out more about the design advantages of high nickel alloy springs – available hot or cold wound. Write for newly-revised Technical Bulletin T-35, "High Nickel Alloy Helical Springs." *Inco trademark



HUNTINGTON ALLOY PRODUCTS DIVISION
The International Nickel Company, Inc.
Huntington 17, West Virginia

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Our engineering and research facilities are constantly developing new and improved methods of solving both simple and complex problems with felt.

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PRICES & SUPPLY

...AT A GLANCE

Price reductions on polycarbonate resins have been announced by Mobay Products Co. and General Electric Co. New price for both GE's Lexan and Mobay's Merlon natural grade resins is $1.50 per lb in 10,000-lb lots. Mobay recently announced availability of Merlon in commercial-scale quantities. GE expects to have its Lexan resin in commercial production by the third quarter of this year.

Copper supply is plentiful. C. M. Brinckerhoff, president of Anaconda Co., says the copper industry can produce 10% more copper than is needed to supply present demand. Other industry spokesmen say that known copper resources are so plentiful that the consumer need not worry about supplies for the next 50 years and beyond. And W. P. Shea, statistician for C. Tennant, Sons & Co., says the price of copper should average 30¢ per lb for the next 15 years.

A 13% cut in the price of polypropylene film was disclosed recently by AviSun Corp. New price is 70¢ per lb in 10,000-lb lots. Meanwhile, AviSun announced plans for the construction of a new plant at New Castle, Del. that will turn out 100 million pounds of polypropylene resin per year.

Production of high purity aluminum is being tripled at Kaiser Aluminum & Chemical Corp.'s Mead, Wash. reduction plant with the installation of six new refining cells. Each cell will have an annual rated capacity of 360,000 lb, making the plant's total capacity for high purity aluminum more than 3,000,000 lb annually. Actual production is expected to begin this fall. Purity of the metal is guaranteed to be 99.99% or higher.

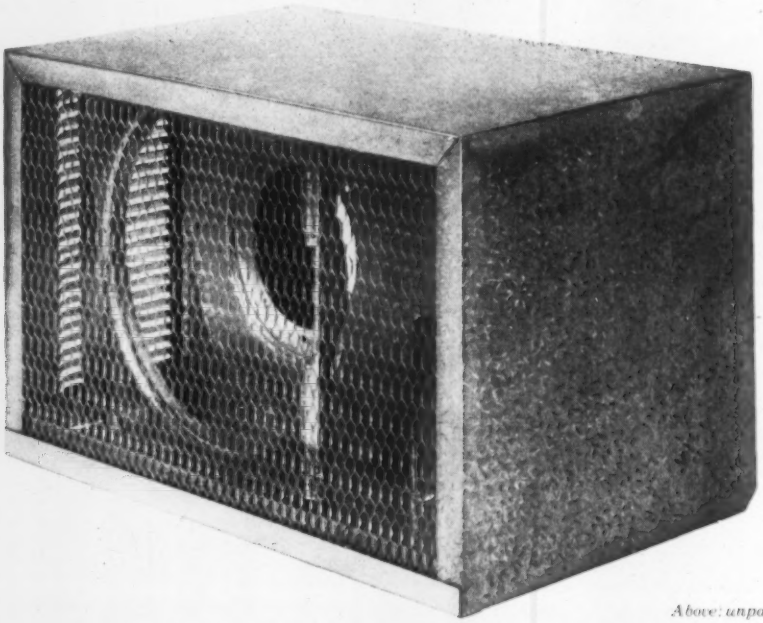
Consumption of synthetic rubber continues to rise. Latest estimates point to a 1960 consumption level of 1,120,000 long tons, up 4.5% from 1959, according to J. W. Keener, president of B. F. Goodrich Co. Keener indicated that natural rubber usage would probably decline by 1 to 2% this year because of its higher current price.

Titanium metal production is 16% ahead of '59 output despite predictions it would decline in 1960. U. S. Census Bureau data show that 1,939,515 lb of titanium mill products were produced in the January-March '60 period, compared to 1,669,037 lb produced in the like '59 period.

Current annual capacity of hot rolled steel products is about 10.2 million net tons higher than in 1957, according to the American Iron and Steel Inst. The new total for all hot rolled steel products is 113,785,590 net tons per year. AISI says 31 states now have hot rolling facilities as against 29 in 1957.

Price of copper magnet wire has been cut 6 to 12% by most of the major wire producers. The 12% reduction applies to round, film-insulated magnet wire in AWG sizes from 8 to 44. A typical grade, No. 34 insulated wire, was reduced from 97.40 to 85.71¢ per lb.

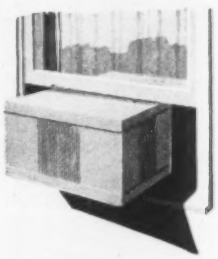
Better Products Through Better Methods and Steels



Above: unpainted air conditioner cabinet

How modern zinc-coated steel sheets keep air conditioners weatherproof—season after season.

When cold-rolled sheet steel formed the cabinets and special drawn base pans of air conditioners, they were primed and painted inside and out to protect them from constant exposure and functional moisture. Even so, corrosion often took hold around fastenings, louver edges and scratches.



Now that Weirkote continuous-process zinc-coated steel is used, the cabinet, louvers and chassis can be cut, bent and formed (even worked to the limits of the steel itself) without chipping or flaking the corrosion resistant zinc surface. When the outside paint finish is applied (primarily for decoration) the air conditioner has the double protection of a coating of paint and a coating of zinc assuring corrosion-free service for many years to come.

It's because of this weather-shedding surface, this superior formability that continuous-process zinc-coated steel is more and more the metal specified for air conditioning, heating and ventilating equipment.

A major supplier: Weirton Steel Company—producer of Weirkote continuous-process zinc-coated steel and many other steels that improve products, methods and profits throughout industry.

For more information, circle No. 366

WEIRTON STEEL
Weirton, West Virginia

Weirton Steel is a division of **NATIONAL STEEL CORPORATION**

Weirkote will also be available in 1961 from National's Midwest Steel Division, Portage, Indiana

Space Age Materials Problems Explored at Aerospace Meeting

Environmental conditions for aircraft have become so severe during the past ten years that it is now necessary to develop materials capable of withstanding temperatures ranging from –423 F to about 4000-5000 F.

Applications and properties of materials

An exploration of these materials problems and some possible solutions was presented at a recent symposium sponsored by Martin Co. The symposium, whose theme was "The Applications and Properties of Materials in Aerospace Vehicle Design," was attended by 200 engineers and scientists interested in materials. It consisted of eleven papers, four panel discussions and a tour of Martin Co.'s Titan ICBM manufacturing, assembling, testing and firing facilities.

The meeting was opened by Clyde Castle, manager of the Engineering Support Dept., Martin Co. Commenting that " . . . no single company should attempt to solve all the materials problems they encounter," he called for freer interchange of information because " . . . few problems are really proprietary . . . and . . . given the time, talent and finances almost anyone could duplicate the activities of others."

Cryogenic temperatures

The technical program was opened by a paper on the behavior of materials at cryogenic temperatures. According to Dr. James Watson, Convair - Astronautics, face-centered cubic materials, such as aluminum and stainless steel, exhibit excellent cryogenic properties, whereas body-centered cubic structures, such as iron, alloy steels and refractory metals, exhibit ductile-brittle transition behavior and are therefore not very well suited to low temperature service.

Ablative materials

An interesting talk on the fabrication of ablative structures was delivered by Elmer Warnken, Cincinnati Testing Laboratories. He described four techniques presently used to fabricate these structures and some new concepts developed from observation of tested structures.

Problems in the design of electrical systems operating under conditions of high humidity and heavy salt concentration were covered by Kenneth Mills, Martin Co. A panel discussion followed in which several speakers described other problems encountered in selecting materials for electrical systems.

Reinforced plastics

Results of studies conducted to determine the effects of low pressure and ultraviolet radiation on the properties of glass-reinforced plastics laminates were described by Norman Wahl, Cornell Aeronautical Laboratories.

Fabrication and use of metals at temperatures above 2000 F were discussed by Saul Bramer, Hughes Tool Co. The metals covered were columbium, tantalum, molybdenum and tungsten. Techniques for forming, machining, assembling and coating these metals were described.

A review of present-day problems facing the designer and materials engineer was given by Richard Agricola, Martin Co. He described the different kinds of properties that must be considered when designing parts for cryogenic, moderate and high temperatures.

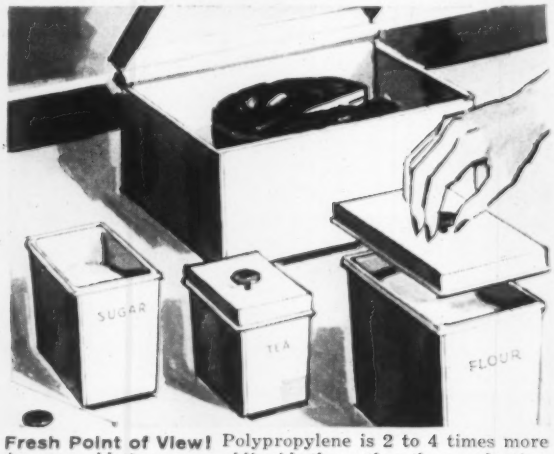
Research Projects on Materials

Five new research projects concerned with the development of new and/or improved engineering materials and processes have been announced recently:

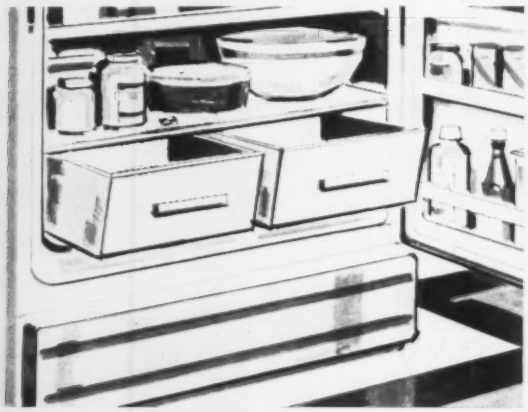
▸ The search for improved materials to withstand the severe temperatures of space travel has led to a $12-million, 3-year research program aimed at developing new graphite materials for missiles and space vehicles. The program, awarded to National Carbon Co. by the Air Force's Research and Development Command, Wright Air Development Div., has four major objectives:

1. Reducing the variation in mechanical and physical properties to about one-third that found in the best grades of graphite presently available.

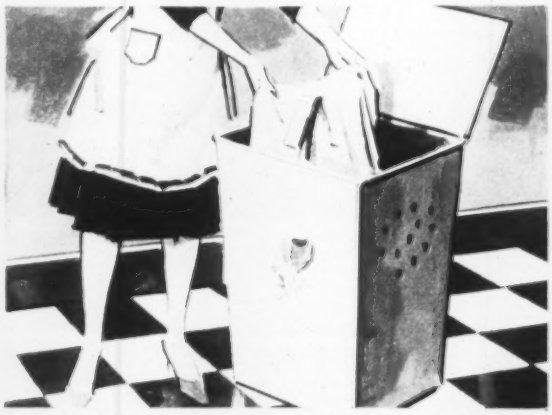
Beats the Heat! Housewares made of Escon get repeated use without warpage. That's because the heat resistance of polypropylene is greater than any other polyolefin. This makes it the desired material for such items as colanders, drainboards, dishpans, tumblers and lighting grilles.



Fresh Point of View! Polypropylene is 2 to 4 times more impermeable to gases and liquids than other thermoplastics. This means freshness stays in, outside elements can't enter. This makes Escon ideal for canister sets, bread boxes and cookie jars—which can be snap-fitted or self-hinged.



Cool Item! Escon is excellent as a food crisper for several reasons. It won't absorb strong food odors and, when properly molded, has the ability to take normal cold without cracking. The design possibilities with versatile Escon are limitless, providing the opportunity to expand existing markets.



New Idea! Escon can be undercut at high speed production cycles. Such items as clothes hampers can be molded in single flat pieces of various colors, then snap-locked for assembly and hinging. This means manufacturers can ship more products in less space . . . retailers will use less storage space, too.

Escon® POLYPROPYLENE

Important news for molders and designers . . .

Escon polypropylene is here! It's the amazing thermoplastic ideally suited to your product needs.

Versatile Escon is easy to work with! It can be injection and compression molded, extruded, thermoformed and heat sealed. Because of its low density, this amazing thermoplastic resin yields more pieces per pound.

For the designer, the high strength of Escon plus its excellent chemical and abrasion resistance allows accurate production of fine and intricate designs with high surface gloss.

For complete information, contact the nearest Enjay office! *Home Office:* 15 West 51st Street, New York 19, N. Y. *Other Offices:* Akron • Boston • Charlotte • Chicago • Detroit • Houston • Los Angeles • New Orleans • Tulsa

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY PLASTICS

For more information, turn to Reader Service card, circle No. 409

News OF INDUSTRY

2. Reducing manufacturing time from many weeks to several days.

3. Developing methods of producing graphite pieces larger than 3 ft in dia by 5 ft long.

4. Developing a processing facility to produce graphite in sufficient quantities for evaluation under full-scale conditions.

▶ Another research contract involving the Air Force has been given to Monsanto Chemical Co. for the development of inorganic polymers. The contract, awarded by the Nonmetallic Materials Laboratory, Wright Air Development Div., calls for the development of polymeric materials with good high temperature properties.

According to Monsanto, research will be aimed at finding inorganic polymers that can be made into elastomers, lubricants and other materials that retain their functional properties at temperatures above the decomposition point of organic materials.

▶ Fundamental research aimed at developing a science of metal wear is now under way at Armour Research Foundation. According to Armour, wear and friction are probably the least understood and the most significant engineering properties of metals to evaluate. The research team consists of metallurgists, physicists, chemists and experts in the field of mechanics.

The approach will be as follows: a family of experimental machines will be developed to measure metal wear and friction. Metal samples will be "forced" to wear, and the extent of wear will be determined by measuring weight loss, changes in dimension and surface damage. These measurements will be made on a selected group of alloys and the general conclusions applied to other metals.

▶ A new technical service laboratory designed to develop and improve products made from over 400 synthetic organic chemicals has been put into operation by Union Carbide Chemicals Co. The laboratory is equipped to provide information and perform research in 29 major areas. Some of these areas are: automotive, petroleum, polyether foams, textiles, plasticizers, surface coatings, and water soluble chemicals.

▶ A die casting laboratory, designed to solve production problems for the automotive industry and other users of magnesium die castings, has been announced by Dow Chemical Co. Work in the laboratory will concentrate on providing data on production rates, casting efficiency, and other factors affecting the use of magnesium die castings.

Welding Engineers Meet in Fall

The National Fall Meeting of the American Welding Society is scheduled to be held Sept 26-29 at the Hotel Penn-Sheraton, Pittsburgh.

The meeting will concentrate on latest developments in welding processes and techniques and will cover such things as percussion and electron beam welding.

The following sessions have been scheduled: welded structures, resistance welding, brazing, electrodes and techniques, research and weldability, processes, rebuilding and surfacing, nondestructive testing, missiles, cutting, aluminum, high alloys, and fabrication of weldments.

Four of the sessions will be sponsored by the American Society of Civil Engineers and two will be sponsored by the Column Research Council of the Engineering Foundation.

For further information, contact American Welding Society, 33 West 39th St., New York 18.

News of Societies

American Foundrymen's Society presented the following awards at its recent Castings Congress and Exposition:

Gold Medals went to Samuel F. Carter, Jr., American Cast Iron Pipe Co., "for exceptional contributions . . . in the fields of cupola melting, electric steel melting and control"; W. W. Levi, Consultant, "for outstanding contributions in the fields of cupola metallurgy research and operation"; and T. D. Stay, Reynolds Metals Co., "for outstanding contributions to the light metals industry, particularly in alloying and castings."

Awards of Scientific Merit went to George P. Halliwell, K. Kramer & Co., for achievements in the field of brass and bronze casting; and George A. Timmons, Climax Molybdenum Corp., for contributions in the fields of heat treatment and alloying of gray iron.

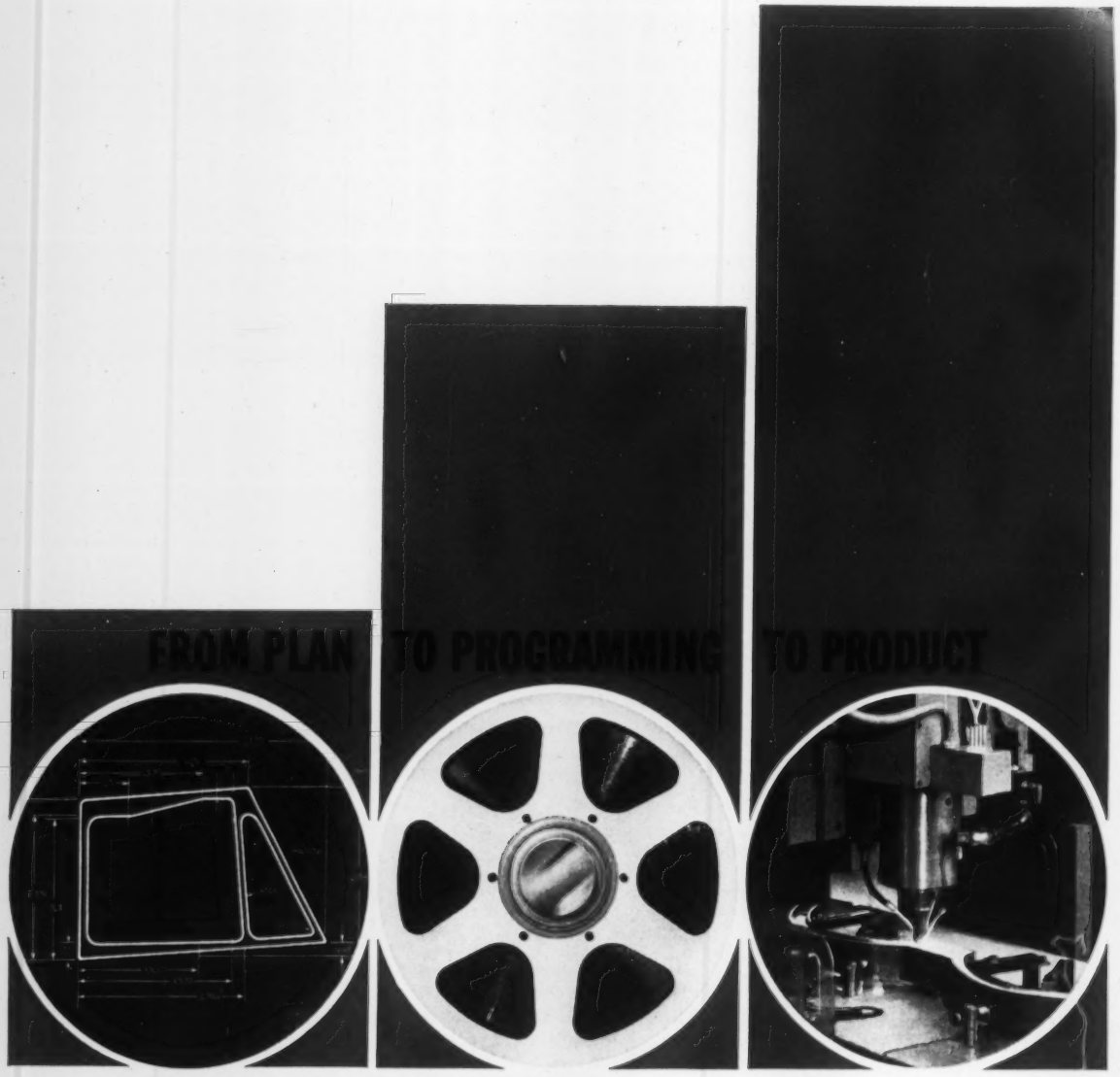
Porcelain Enamel Institute has announced the appointment of Robert S. Thompsen, Babcock and Wilcox Co., to the newly-created position of Manager of Technical Activities.

National Institute of Ceramic Engineers has presented its Professional Achievement in Ceramic Engineering Award to Dr. James R. Johnson, Minnesota Mining & Mfg. Co. The award, which was presented at the annual meeting of American Ceramic Society, Inc., is given "to the outstanding young member of the ceramic industry for contributions to advancement of the ceramic engineering profession and to the general welfare of his community."

American Society for Metals has formed an ASM Technical Council to further the Society's "technical objectives through supervision and coordination of the Society's technical committees." George A. Fisher, International Nickel Co., is 1960 chairman of the Council.

Aluminum Assn. has elected the following officers: president—M. M. Anderson, Aluminum Co. of America; chairman of the board—S. D. Den Uyl, Bohn Aluminum & Brass Corp.; vice presidents—N. H. Collisson, Olin Mathieson Chemical Corp.; John W. Douglas, Republic Foils Inc.; and Thomas D. Gebhart, Anaconda Aluminum Co.

Coming Meetings on p 31 ⟶



COMPLETE NUMERICAL CONTROL SERVICE FROM ROHR. Rohr Aircraft Corporation has established a complete, ***in-plant*** Numerical Control Department, offering a full range of services that can be tailored to any requirement. If you use numerically controlled machine tools, or recognize the method's superiority, this new service will interest you.

Rohr can provide complete service—tool planning, tool manufacture, part programming, computer processing, tape or card preparation, final part machining—or any part of the service separately.

If you own a machine, for example, Rohr will produce tape or card media from your plans. Or you may need to employ only computer or director service. Whatever your numerical control needs, this fully flexible service can meet them.

Rohr's recognized leadership in the use of numerically controlled machine tools and in programming stems from an early realization of the method's potential in production of uniform, close-tolerance parts. Studies began more than a decade ago—years before the first machines were built. Today, Rohr's complete facilities, practical experience, and highly trained staff combine to provide an unparalleled capability in numerical control.

A new brochure describes Rohr's numerical control services in detail.
Write Mr. A. R. Campbell, Sales Manager, Rohr Aircraft Corporation, Chula Vista, California.

ROHR AIRCRAFT CORPORATION

WORLD'S LARGEST PRODUCER OF COMPONENTS FOR FLIGHT • CHULA VISTA AND RIVERSIDE, CALIFORNIA

For more information, turn to Reader Service card, circle No. 432

News OF INDUSTRY

Coming Meetings

4TH NATIONAL HEAT TRANSFER CONFERENCE AND EXHIBIT, American Inst. of Chemical Engineers and American Society of Mechanical Engineers. Buffalo, N.Y. Aug 14-17.

SOCIETY OF AUTOMOTIVE ENGINEERS, INC., national West Coast meeting. San Francisco. Aug 16-19.

PRODUCTION ENGINEERING SHOW. Chicago. Sept 6-16.

6TH MACHINE TOOL EXPOSITION, National Machine Tool Builders' Assn. Chicago. Sept 6-16.

AMERICAN CHEMICAL SOCIETY, 138th national meeting. New York City. Sept 11-16.

ELECTRONIC INDUSTRIES ASSN., fall meeting. French Lick, Ind. Sept 13-16.

AMERICAN DIE CASTING INSTITUTE, annual meeting. Chicago. Sept 14-15.

STEEL FOUNDERS' SOCIETY OF AMERICA, 58th fall meeting. Hot Springs, Va. Sept 18-20.

POWER CONFERENCE, American Society of Mechanical Engineers and American Inst. of Electrical Engineers. Philadelphia. Sept 21-23.

NATIONAL FOUNDRY ASSN., annual meeting. Chicago. Sept 22-23.

AMERICAN WELDING SOCIETY, INC., national fall meeting. Pittsburgh. Sept 26-29.

15TH ANNUAL INSTRUMENT-AUTOMATION CONFERENCE AND EXHIBIT, Instrument Society of America. New York City. Sept 26-30.

ASSN. OF IRON & STEEL ENGINEERS, annual meeting and exposition, Cleveland. Sept 27-30.

RUBBER AND PLASTICS CONFERENCE, American Society of Mechanical Engineers. Erie, Pa. Oct 9-12.

NATIONAL ELECTRONICS CONFERENCE, INC., 16th annual NEC meeting. Chicago. Oct 10-12.

PRESSED METAL INSTITUTE, annual meeting. Shawnee-on-the-Delaware, Pa. Oct 10-14.

SOCIETY OF THE PLASTICS INDUSTRY, INC., 16th annual New England Section conference. Wentworth-by-the-Sea, Portsmouth, N.H. Oct 13-14.

MAGNESIUM ASSN., annual convention. Cleveland. Oct 17-18.

42ND NATIONAL METAL EXPOSITION AND CONGRESS, American Society for Metals. Philadelphia. Oct 17-21.

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the most complete line of

coated fabrics for industry

The REEVECOTE line of natural and synthetic rubber coatings is the most complete source of engineered industrial coated fabrics available to the design field today.

Reeves Brothers *research—development—quality control*—guarantee that REEVECOTE will meet the required specifications in your industry. Whether it's resistance to high temperature, oil or abrasion—or flexibility at low temperature or room temperature, or any other special requirements, there's a REEVECOTE designed to do your job.

That's why, if a coated fabric is used in your design *always specify Reevecote.*

REEVES VULCAN

Reeves Brothers, Inc., Vulcan Rubber Products Division
1071 Avenue of the Americas • New York 18, New York

For more information, turn to Reader Service card, circle No. 406

"I want a tube with a controlled inside diameter"

"I want to get more tube surface for heat transfer"

"I want long coils that can fit into my production line"

"I want more than just a tube!"

Men who know tube want just a little bit *more* when they buy.

If they are interested in heat exchange, for example, they weigh carefully the advantages of using capacity-boosting Wolverine Trufin®—an integrally finned tube.

If they have to meter a liquid, gas or air—get just the precise amount for a given application—they insist upon precision-made Wolverine Capilator®.

And if they have to step up production of tubular shaped parts while saving premium floor space and inventory, they go for Wolverine level-wound coils.

All of these are Wolverine developments. All of them have been designed to answer a customer want. In petroleum processing—in air conditioning and refrigeration—in metal-working—in many, many industries, products like these are providing engineers with more than just a tube.

And Wolverine research and development promises even bigger developments. They'll be designed to solve customer needs in the fields above along with plumbing, power, electrical, nuclear and many others.

Yes, men who know tube, know the difference. It's Tubemanship! Write for your copy of the Wolverine Tubemanship book today.

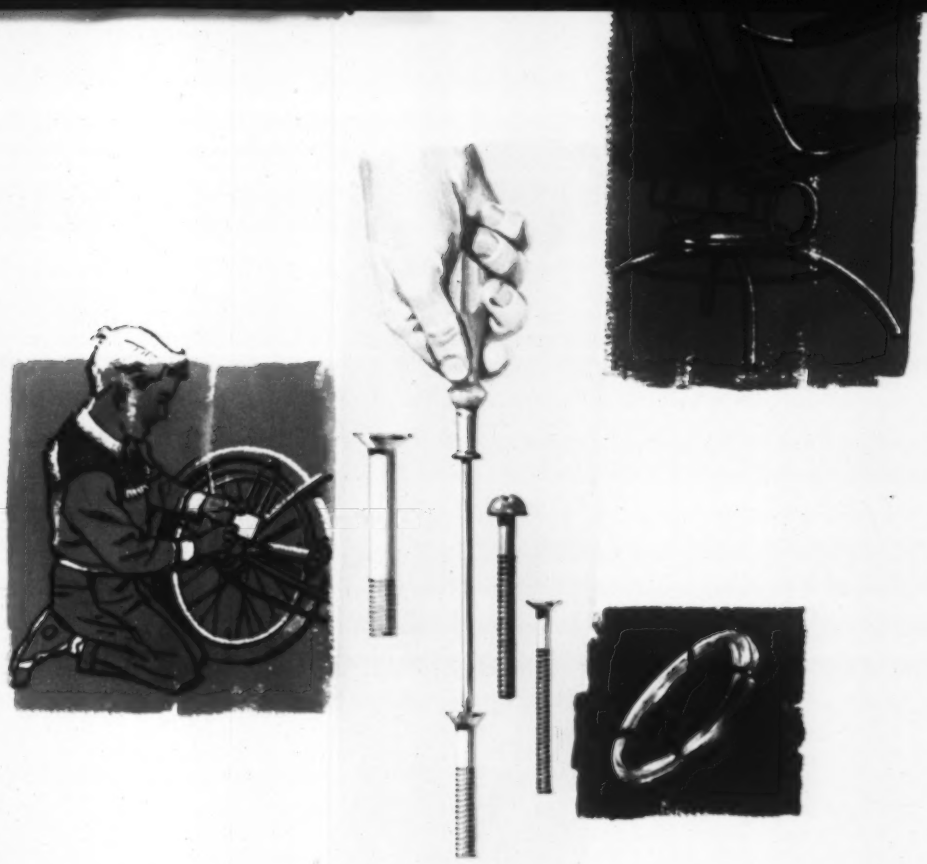
WOLVERINE TUBE
DIVISION OF
Calumet & Hecla, Inc.
DEPT. D, 17258 SOUTHFIELD RD., ALLEN PARK, MICH.
Manufacturers of Quality Controlled Tubing

J-5023

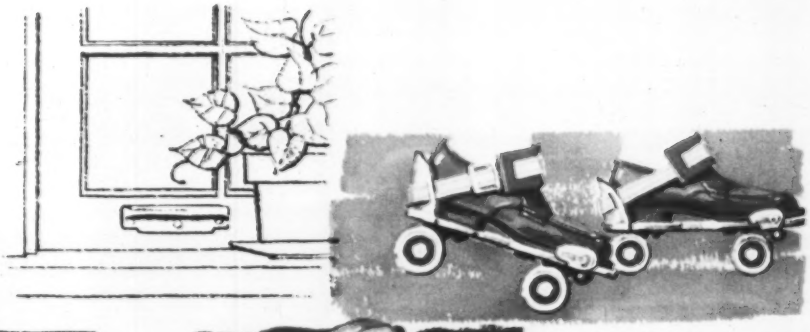
PLANTS IN DETROIT, MICHIGAN AND DECATUR, ALABAMA. SALES OFFICES IN PRINCIPAL CITIES.

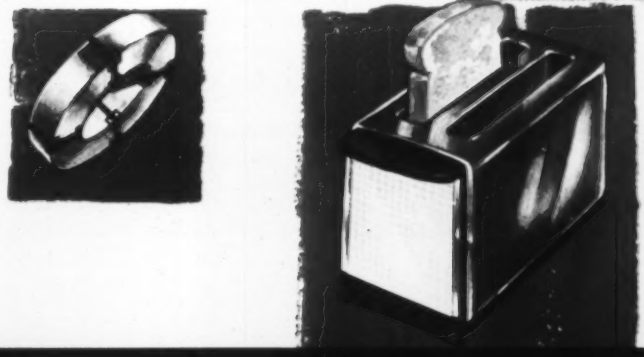
For more information, turn to Reader Service card, circle No. 434

For more information, circle No. 422



Quality products call for quality wire, bars and strip . . .





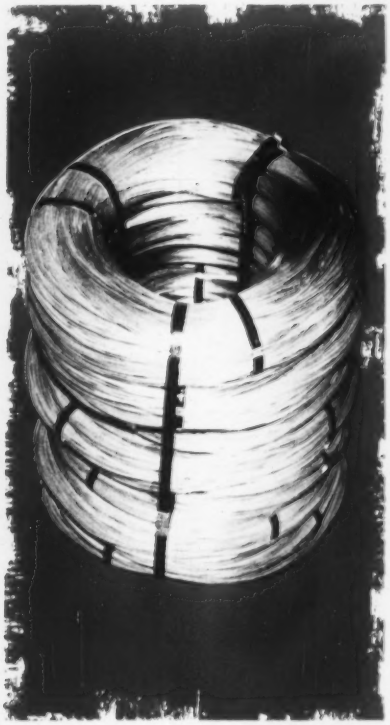
USS

American Steel & Wire
Division of
United States Steel

USS American Quality Manufacturers Products packaged to speed up handling and save storage space

Standard Coils: American Steel & Wire manufactures standard coils in weights suited to your material handling equipment.

Heavyweight Coils: These continuous wire coils, weighing up to 2,000 pounds, speed up your production by reducing down time for setups and changes. One large coil takes the place of several smaller coils of same total weight—are much easier to handle . . . require much less storage space.



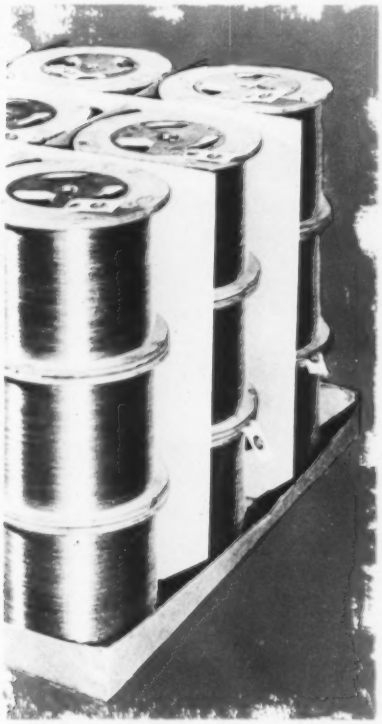
Unitized Coils: These unit packs offer great savings in handling time and storage space. One unit, containing several coils, is easily handled; takes up less storage space than the same coils stored separately.

. . . quality controlled to help you make good products better

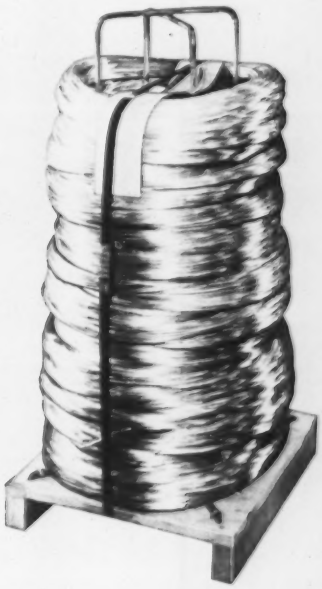
To mass produce this bicycle padlock the Master Lock Company uses USS Amer-Led Steel Bars. This leaded steel permits increased machining speed over equivalent non-leaded grades. The use of USS Amer-Led results in more accurate forming; . . . fewer rejects.

American Steel & Wire products and service facilities are available to you at no increase in cost. It will pay you to use these advantages. The quality and uniformity of USS American Manufacturers Wire brings you production economies through easier processing and fewer rejects. It makes a superior finished product that is more salable. And it is available in all the modern money-saving forms:

Pay-off Drums: Long-run continuous coils of wire are packed and delivered in heavy fibre containers. These Pay-off Drums are easy to handle and stack for storage. These are ideal for use where wire finish requires special protection from dirt and corrosive atmospheres. Available in most wire sizes with length and weight of coil to your specifications. You do not need to return drums.



Disposable Spools: These new non-returnable spools can be supplied with any amount of fine wire—from 5 lbs. to 100 lbs. These are easy to handle individually, and when shipped in quantity are delivered 36 to a pallet, ready for storage.



Platform Coil Carrier: The disposable platform carrier, made up of a U-shaped wire frame fastened to a platform, holds up to 3,000 pounds of special wire in one continuous length. It is often ideal for ordering and handling quantities of wire.

American Screw Company turns out 14 million recessed head fasteners a day. Their most famous patent is the Phillips Head Screw, for which American Steel & Wire developed a special cold heading wire, hard enough to produce strong, tough fasteners, yet soft enough to avoid splits and cracks when the Phillips punch is rammed into the coning blank.

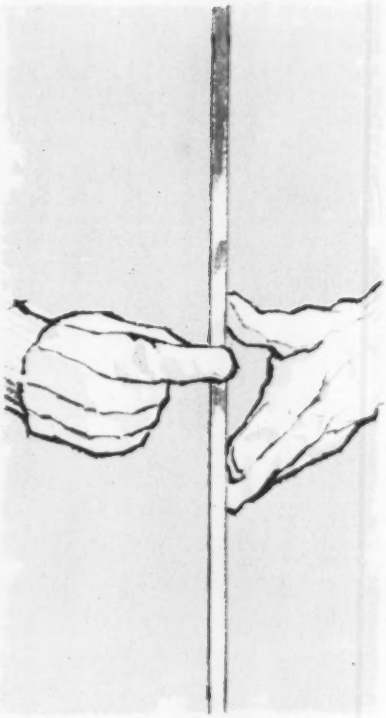
The pair of round wire helical single coil torsion springs on this chair were specially made for the Homecrest Company of Wadena, Minnesota. Under a 250-pound weight, the chair was test rocked 750,000 times without showing any sign of failure. *Another success story for USS American Manufacturers Products.*

American Steel & Wire
Division of
United States Steel

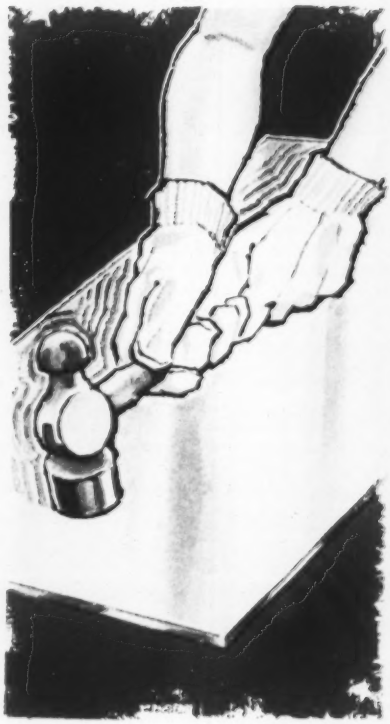
USS

USS Amerstrip . . . gives you precisely what you need in a cold rolled strip

Precision Finish. With USS Amerstrip we take special pains to give you a finish that is just right for the specific results you require in a finished product. We believe the Amerstrip finish is the finest you can get in the industry.

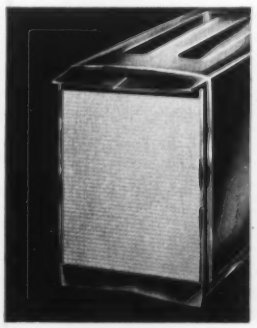


Precisely Prepared Edges. Because USS Amerstrip is produced in order-sized quantities engineered to your own specifications, we can give you exactly the edge finish you need—square, standard, round, full round or bevel.



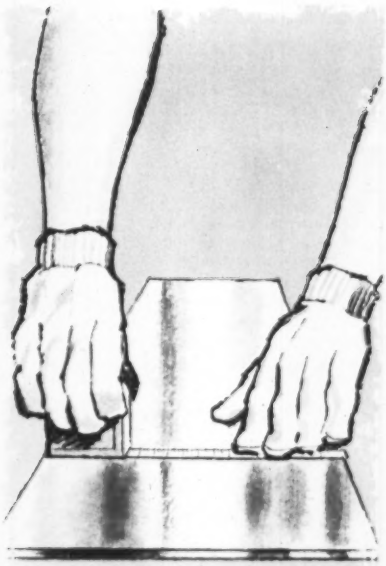
Precise Tempers. Whether your product must go through a deep draw or undergo other stringent forming operations, or if it requires a special temper for rigidity, you'll get the correct temper for the job when you order USS Amerstrip.

. . . to speed up production and keep your product quality high!



Much of the sales-pulling beauty of Proctor Electric Company's modern toaster is due to the use of gold-finished, geometric-patterned USS Embossed Amerstrip. American Steel & Wire specializes in the rolling of special embossed designs such as this for specific applications. Perhaps you, too, have a product which could be made more beautiful and more sales appealing with Embossed Amerstrip.

USS Amerstrip is a specialty product that has opened vast new production and sales possibilities for a growing number of alert manufacturers of consumer products. It is available in a variety of attractive finishes—plain or embossed. It permits production on precision machines. When you use USS Amerstrip, you get six distinct advantages not easily obtainable with other manufacturing methods or materials:



Precise Width Tolerances. When your fabricating machines require a special width strip, you can be sure that's the width you'll get. We can produce USS Amerstrip within required tolerance limits to fit your special requirements.

Precise Thickness Tolerances. Whatever the thickness tolerance your machines demand, USS Amerstrip can give it to you. We can roll Amerstrip down to thickness tolerances of plus or minus .0005 inches.

Precise Uniformity. Regardless of the size of your order every coil of USS Amerstrip comes off the line uniform in finish, temper, width and thickness. In short, USS Amerstrip's precision production assures a continuous run and high yield.

Amerstrip is used in the manufacture of almost every part of the 15 types of Hustler Corporation skates made by Frantz Manufacturing Co. These skates will stand up under the punishing wear children may give them—yet maintain their attractive finish. Amerstrip is tailored to each particular job . . . has the physical properties to assure a good performance and efficient manufacture.

Amerock Corporation of Rockford, Illinois, makers of sash lifts, had trouble finding a strip steel that would meet its severe double drawing operation requirements. They brought the problem to American Steel & Wire. Our metallurgists recommended a type of USS Amerstrip tailored to their deep drawing requirements and capable of holding a finish suitable for plating.

American Steel & Wire
Division of
United States Steel

USS

Facilities and service second to none!

As the country's largest manufacturer of wire and strip, we offer a *single source of supply* for all your varied manufacturers' wire and strip requirements.

Widespread *modern facilities* assure that your product will be made exactly to specification, thoroughly uniform in quality and dimension.

Experienced sales representatives are at your service to assist in determining how USS American Manufacturers Products can help make *your* product better.

For more detailed information, get in touch with the nearest district office. American Steel & Wire, 614 Superior Ave., N.W., Cleveland 13, Ohio.

USS, American and Amerstrip are registered trademarks

American Steel & Wire
Division of
United States Steel

This mark tells you a product is made of modern, dependable Steel.

PRODUCT-DESIGN BRIEFS FROM DUREZ

- Something extra in molding compounds
- Fire-retardant structural plastic
- News notes for designers

Upgrading a product

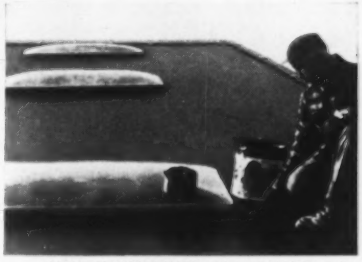
Good • Plenty of distributor caps are molded of Durez general-purpose phenolic. When cost is a prime factor, general-purpose does the job and does it well.

Best • However, if you're shooting for something extra in a distributor cap (or in almost any electrical part), take a look at *Durez 2271*. This is an electrical-grade phenolic. A ⅛" test disk of it withstands 12 kv at 180°F in air for an hour or more without puncturing. The cost of this extra performance is low: weighing less than comparable electrical-grade materials, *2271* gives you more pieces per pound.

Good • You'd be right in choosing *Durez 791 Black* for a piece like this telephone handset. You'd be able to count on low molding cost because of *791's* fast cure. You'd get the required physicals in good balance. And the price of this wood-flour-filled material is low.

Best • Then why do telephone men favor a different material, *Durez 17225*, for handsets? Because this wood-flour-and-flock-filled material provides even higher resistance to impact fractures. The rich black finish presents an unyielding front to moisture and body acids. Bonus: a part that *more* than meets the specs—for fractions of a penny per piece.

We could go on and on giving you case histories like these. Have you looked into the extras you can build into a product—at next-to-invisible cost—with Durez molding materials? To get a better idea of what these compounds can do for you, send for our illustrated 8-page Bulletin D400 listing properties, uses, advantages.



CONSOLITE (CONSOLIDATED GENERAL PRODUCTS, INC.)

Safer skylight

Here's a plastic skylight that retards fire.

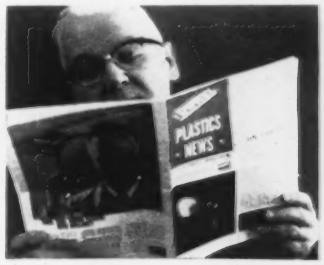
It's made for use in hazardous locations or wherever building codes are exceptionally strict.

The material is fibrous-glass-reinforced Hetron®. It will ignite only under direct hot flame, and snuffs out as soon as the flame source is removed.

Weighing only half a pound per square foot, the skylight material will support a uniform load of 150 pounds per square foot. It is thermally stable from −65° to 200°F, and has great strength and shatter resistance even at subzero temperatures.

Its thermal conductivity is only ⅛ that of glass, yet it can transmit ⅘ as much light as glass without glare. It delivers greater insulating effect than other skylight materials, at lower cost.

Could any of these attributes help *you* design a better product? Hetron® is hard at work already in radomes, chemical ducts, blowers, boat hulls, housings, fume hoods, window panels, canopies. Data on self-extinguishing Hetron resins is yours for the asking.



On keeping abreast

How can a man keep up with all that's new in thermosetting plastics?

Well, it isn't easy. But we can help. We mail out every 60 days a bulletin, *Durez Plastics News*. You can read it in 10 minutes. It gives a bird's-eye view of what's new in the use of Durez plastics. Every item is *news*—hot off the presses of leading molders the country over, whom we visit regularly.

To get this bimonthly packet of ideas and information, just check the coupon.

For more information on Durez materials mentioned above, check here:

- ☐ Phenolic molding compounds (8-page Bulletin D400).
- ☐ Hetron fire-retardant polyester resin (data file).
- ☐ *Durez Plastics News* (mailed bimonthly).

Check, clip, and mail to us with your name, title, company address.
(When requesting samples, please use business letterhead.)

DUREZ PLASTICS DIVISION
1408 WALCK ROAD, NORTH TONAWANDA, N. Y.
HOOKER CHEMICAL CORPORATION
HOOKER CHEMICALS PLASTICS

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▲ For more information, turn to Reader Service card, circle No. 342

in only 90 days...

101 aluminum fabricators have ...Amchem's newest

ALODINE 1200S protects aluminum best ...at less cost, in less time!

To the hundreds of long-time users of Amchem Alodine—the first, low cost effective surface conversion treatment for aluminum—add a new host of fabricators who are employing the newest Alodine development—ALODINE 1200S!

If you are producing aluminum—any type of aluminum—you'll want to investigate the production advantages and profit potentialities of this new Alodine pre-paint process that provides constant, uniform quality as well as big savings in time, equipment and processing costs!

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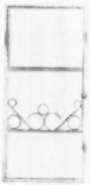
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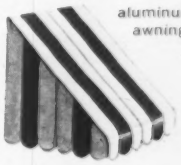
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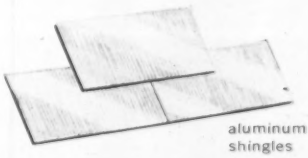
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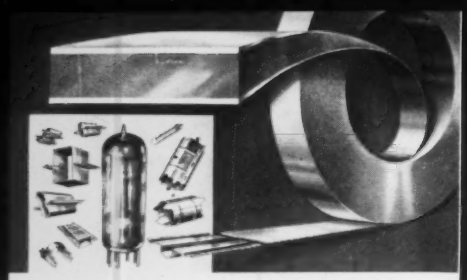

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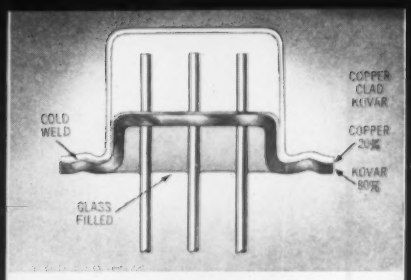

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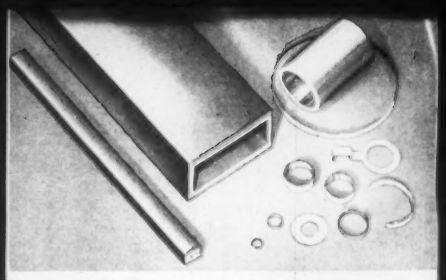

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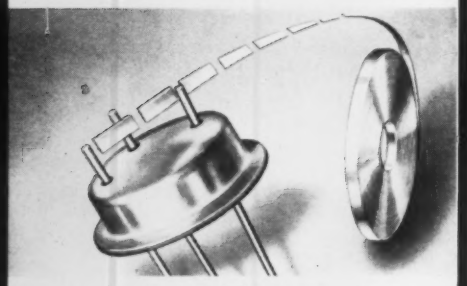

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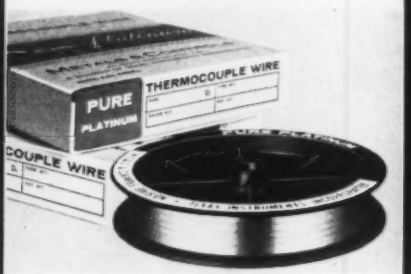

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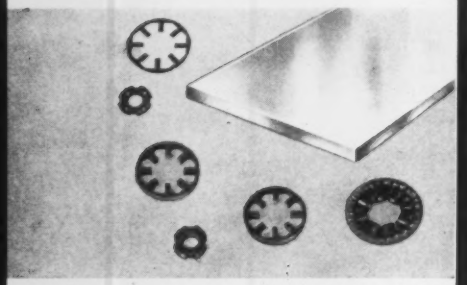

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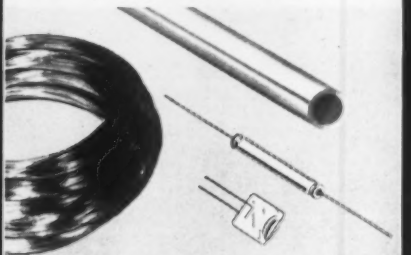

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Adhesives, Coatings. Raybestos-Manhattan, Inc., Adhesives Dept., 16 pp, illus., No. 700. Properties and uses of adhesives, coatings and sealers manufactured by the company. **168**

Fusion Welding Aluminum. Reynolds Metals Co., Dept. PRD-31, Richmond 18, Va., 32 pp. Gas welding, metal arc welding, tungsten inert gas welding, and metal inert gas welding of aluminum. Also covered is welded joint design. Write on company letterhead directly to Reynolds.

Methods & Equipment • Testing

Hardness Tester. Wilson Mechanical Instrument Div., American Chain & Cable Co., Inc., 2 pp., illus., No. TT-58. Dimensions, features, operational data and prices of a Rockwell hardness tester. **178**

Measuring Instruments. Riehle Testing Machines, Div. of American Machine & Metals, Inc., 12 pp, illus., No. RM-560. Specifications, characteristics, advantages and uses of a line of instruments used to measure force and distance. **169**

Processing X-Ray Films. Eastman Kodak Co., X-Ray Div., 6 pp, illus. Describes an entirely new system of faster, better processing for industrial X-ray film. **170**

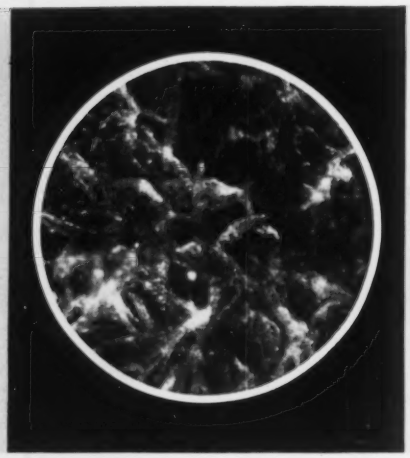
Electric Furnaces, Kilns. Pereny Equipment Co., 8 pp, illus. No. 570. Information on electric heat treating, melting and sintering furnaces, and electric ceramic kilns. **171**

Metal Powder Press. F. J. Stokes Corp., 4 pp, illus., No. 1200. Outstanding design features, special characteristics, advantages, specifications and operating characteristics of a 50-ton multiple motion powder metal press. **172**

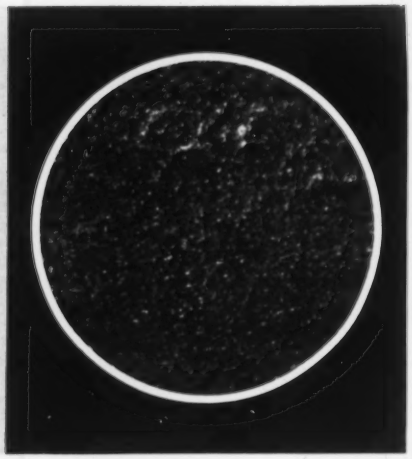
Temperature Indicators. Tempil Corp., 1 p, illus., No. 5910TS. Information on a complete line of available temperature indicators, including instructions for use. Covers such things as checking temperatures of rotating parts, visibility on brightly radiating hot surfaces, and effects of reducing atmospheres in electrical fields. **173**

Testing Materials. United States Testing Co., Inc., 6 pp, illus. Information on testing design and development of adhesives, ceramics, fabrics, metals, plastics and rubber. **174**

Photomicrograph, 300x magnification, shows coating structure produced by conventional phosphating treatment.



Fine-grained coating, shown in photomicrograph at 300x magnification, produced on steel by Bonderite 890.

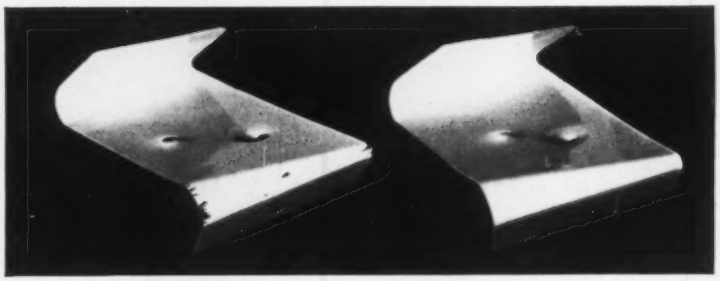


Finer Parker phosphate coating improves adhesion of new "hard" paints

Here is a Bonderite developed to meet the exacting requirements of the new "hard" paints —the epon and acrylic finishes so popular with manufacturers and their customers.

Bonderite 890 forms a microcrystalline coating on steel. It is so finely crystalline that it is commonly referred to in industry as amorphous. The coating withstands an extraordinary amount of flexing of the metal underneath, with little shearing or dusting even under severe bending or denting.

Finishes applied over Bonderite 890's fine grained coating gain greater adherence and flexibility. Epons and acrylics withstand deformation without signs of failure.



Steel panels, finished with an acrylic enamel and bent on a conical mandrel. Unretouched photos show paint flaking over conventional phosphate treatment (left), and excellent paint retention over Bonderite 890 (right).

FINE RESULTS AFTER HEAVY-DUTY CLEANERS

Regardless of the cleaning method used, Bonderite 890 coatings are uniformly hard and dense. This removes all restrictions on the utilization of medium and heavy-duty alkaline cleaners to handle heavy dirt, grease and soil. You get high quality paint base coatings after any type of cleaner, when you use this specially developed Bonderite.

WANT MORE INFORMATION?

The Parker representative near you can give you details on Bonderite 890 and the benefits it may bring to your plant and your production. Call him in, or write Parker, Detroit.

Parker Rust Proof Company
2173 E. MILWAUKEE, DETROIT 11, MICHIGAN

Since 1914— leader in the field

BONDERITE corrosion resistant paint base • BONDERITE and BONDERLUBE aids in cold forming of metals • PARCO COMPOUND rust resistant • PARCO LUBRITE—wear resistant for friction surfaces • TROPICAL—heavy duty maintenance paints since 1883

*Bonderite, Bonderized, Bonderlube, Parco, Parco Lubrite—Reg. U.S. Pat. Off.

For more information, turn to Reader Service card, circle No. 374

Materials, forms, finishes
. . . and related products . . .

Advertised in this issue

USE THIS INDEX TO...

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Get more information on advertised products by circling the key numbers found on the advertisements (*not* the page numbers below) on the free postal card, pp 43-44.

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For free technical literature on all kinds of engineering materials, forms and finishes, see pp 45-49.

Only one of sixty materials met these tough filter specifications

Troyfelt, a non-woven synthetic Dacron, gave best performance in military vehicle engine.

The specifications? Ability to produce nearly 100% filtering efficiency in heavy dust conditions, in temperatures from -65 to 275°F, resistance to oil, moisture, rot and mildew. The product? The filter on a heavy duty engine intake air cleaner on a military vehicle. The result? Out of sixty materials tested, only one, TROYFELT, did the job.

The secret behind TROYFELT'S success is its specialized manufacturing process of mechanically interlocking the Dacron, Orlon and other special synthetic fibers rather than chemically binding them or introducing binder fibers. This method eliminates the old filter "bugaboo" of blinding caused by such binders or binding agents and gives TROYFELT its unusually high, long-lived strength, excellent resistance to fungi and bacterial growth, chemicals, moisture, oil, abrasion, stability to temperature extremes and many others.

But, filtering is only part of the TROYFELT story — other applications for this remarkable material include insulators, seals, padding, packings, gaskets and many others. We'll be glad to send you our bulletin describing most of them and samples.

TROYFELT ... *by the pioneers in non-woven synthetic felts*

INDUSTRIAL PRODUCTS DIVISION • TROY BLANKET MILLS

200 Madison Avenue • New York 16, New York

For more information, turn to Reader Service card, circle No. 354

For more information, circle No. 423

working with

Du Pont Zytel®

one of Du Pont's versatile engineering materials

Turbine fan of ZYTEL® makes possible radical design

A difficult design problem in Sunbeam's new de luxe vacuum-cleaner line involved the turbine brush sweeper accessory. The turbine brush combines the advantage of a power-driven brush, previously found only on uprights, with the power and flexibility of a tank-type cleaner. This brush is powered by a unique one-piece fan wheel made up of 54 curved blades, spaced to allow the intake of metallic objects such as paper clips, hairpins and the like.

For satisfactory operation of this turbine wheel, an exceptional material was required—one with high strength in thin sections, resilience, and resistance to metallic impact. The material had to be intricately molded to close tolerances in an economical one-piece molding. In addition, lightness of weight, abrasion resistance, and good bearing properties were needed. The solution: a wheel molded of Du Pont ZYTEL nylon resin, which fulfilled all these requirements. The successful design of this component, molded by Chicago Molded Products Corporation, for Sunbeam Corporation, both of Chicago, Illinois, also permitted the over-all design of the sweeper unit with a low profile for maximum furniture clearance.

On the following page, you will find some additional examples of the basic design improvements made possible by the use of ZYTEL nylon resins.

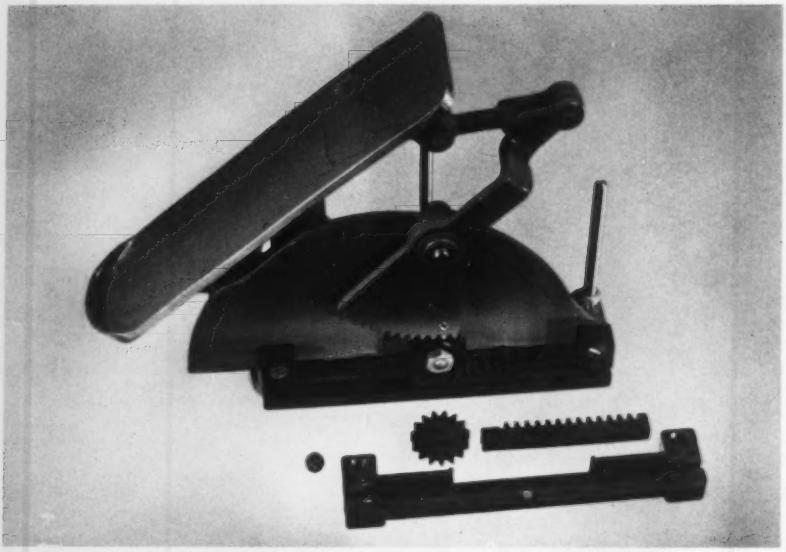
DU PONT
REG. U.S. PAT. OFF.
BETTER THINGS FOR BETTER LIVING
...THROUGH CHEMISTRY

working with

Du Pont Zytel®

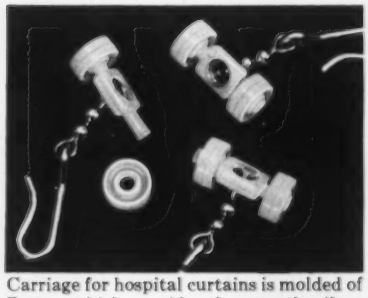
nylon resins

one of Du Pont's versatile engineering materials



Full-throttle foot control for motor boats is made with gear, rack, guide panel and anchor ball of ZYTEL nylon resins. The rack and anchor ball have threads molded in to accept the control cable and sheath respectively. The use of ZYTEL assures smooth, quiet operation of the foot control, and eliminates salt-water corrosion problems. In addition, the unit requires no lubrication. (Molded by Nylon Products Corporation, Clinton, Massachusetts, for Tempo Products Company, Cleveland 3, Ohio.)

Sleeve bearings for heavy machinery are made with sleeves of ZYTEL, reinforced with a steel backing that has indented perforations and press-fits into the bearing housing. The good flow characteristics of ZYTEL enable it to flow easily into place through and around the many perforations. ZYTEL provides the necessary abrasion resistance, impact strength and low noise factor. (Molded by Terhorst Manufacturing Company, Minot, N. D.)



Carriage for hospital curtains is molded of ZYTEL, which provides the smooth, silent operation required in hospitals. This long-wearing part is easily assembled by snap fitting, needs no lubrication. (By Capital Cubicle Company, Brooklyn, New York.)

Designed with ZYTEL®
for smooth, quiet operation

The products on this page demand smooth, low-noise operation, as well as varying degrees of strength, abrasion resistance, corrosion resistance, and freedom from lubrication problems. In each case, the use of ZYTEL meets the combined design requirements and helps assure long, trouble-free operation.

Du Pont ZYTEL may help you, too, to save money by reducing production costs and giving improved performance under a variety of difficult conditions. Find out how by sending in the coupon. Also, ask for the new booklet on the properties and advantages of tubing of ZYTEL.

POLYCHEMICALS DEPARTMENT

DU PONT

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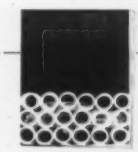
BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY



E. I. du Pont de Nemours & Co. (Inc.)
Room 2507Z, Dept. B: 1
Nemours Building, Wilmington 98, Delaware.

☐ Please send me the booklet on tubing of ZYTEL.
☐ I am interested in evaluating ZYTEL for the following use:

*Name*_____

*Company*_____ *Position*_____

*Street*_____

*City*_____ *State*_____

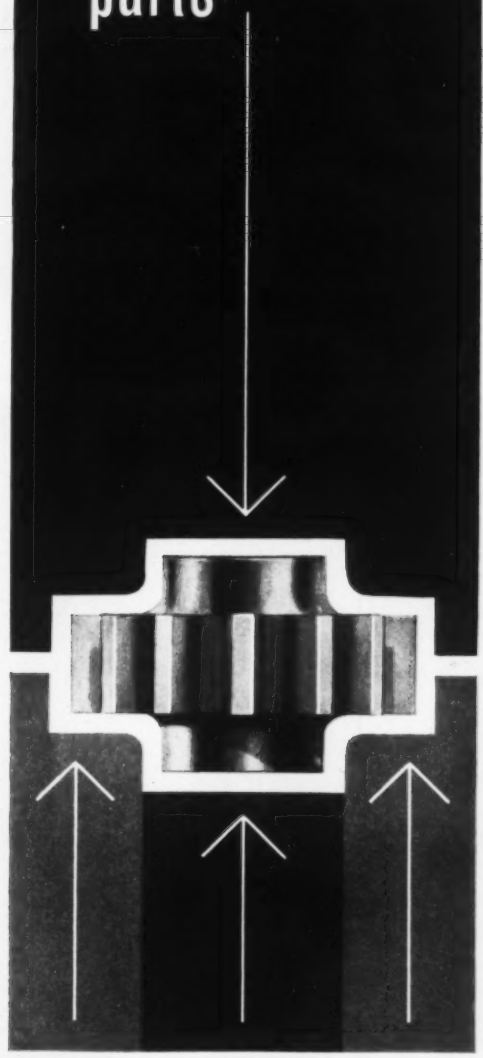
In Canada: Du Pont of Canada Limited, P. O. Box 660, Montreal, Quebec.

ZYTEL® *nylon resins*

one of Du Pont's versatile engineering materials

Alathon® · Delrin® · Lucite®

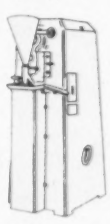
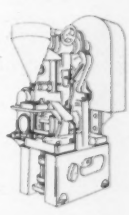
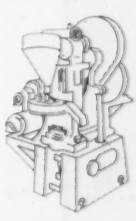
EXTRA MOTION for complex powder metal parts



Stokes answers the growing need for extra motions in the manufacture of more complex parts by adding three *new* machines to its extensive line of compacting presses. In each compacting press, the design of the secondary lower motion enables the operator to adjust timing, duration, and length of thrust independent of the mechanical timing of the preset main operating cycle of the press. The built-in secondary lower motions may be used as compacting punches or core-rods (stationary, movable, stripping, or ejection type).

These low and medium-pressure presses give you all the advantages you would expect to find in a Stokes press . . . accuracy, high production rates, ease of adjustment, and little maintenance . . . *plus extremely flexible lower motions.*

SINGLE-STATION MULTIPLE MOTION PRESSES

Model 572-1	Model 573-1	Model 574-1
4 TONS	12 TONS	20 TONS
		
4 TONS + 1 TON	12 TONS + 3 TONS	20 TONS + 5 TONS

For complete technical data on these single-station multiple motion presses, write for Data Sheet 126. Consult Stokes Engineering Advisory Service for complete technical assistance in designing parts, punches and dies, or complete production facilities.

STOKES

POWDER METAL PRESS DIVISION • **F. J. STOKES CORPORATION** • 5500 TABOR ROAD, PHILADELPHIA 20, PA.

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Schlieren photograph showing heated air rising from Malleable chain link at 1200° F.

For Hot Parts... Use Malleable

Heat them up, cool them off—ten thousand times. Heat them up, keep them hot—indefinitely . . . you'll find you can count on Malleable iron castings for an exceptional combination of safety and economy.

New research demonstrates that the rugged room-temperature characteristics of Malleable castings remain virtually unchanged up to 800° F! More important—from 800° F. to 1,200° F., Malleable castings are unique in providing safe, dependable service **without** sudden drop in strength.

Let a nearby Malleable castings producer help you develop better, more economical parts for elevated temperature applications. Send drawings or an outline of your requirements to any of the progressive companies that display this symbol—

MEMBER

MALLEABLE CASTINGS COUNCIL

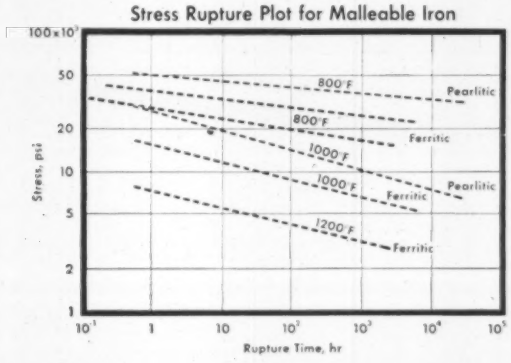
For detailed information on "Use of Malleable Castings in Elevated Temperature Applications," contact any company listed on the opposite page, or Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

Get Dependable Strength At Elevated Temperatures With Tough, Economical Malleable Castings

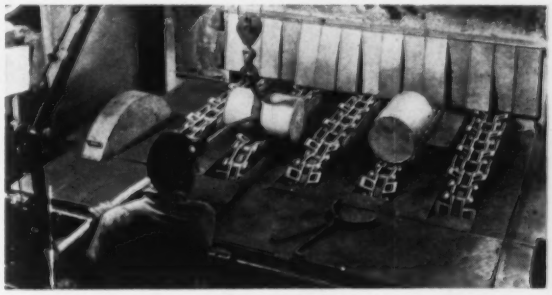
Malleable iron castings give you excellent service under rugged conditions at temperatures up to 800F. Even at temperatures as high as 1200F, at reduced stress levels, Malleable castings offer uniformly predictable properties.

Compare these stress-rupture curves for Malleable iron with other ferrous metals. Malleable's are straight, gradually declining curves . . . not curves that break sharply and suddenly downward. With Malleable you can count on long life.

Stress Rupture Plot for Malleable Iron



At temperatures from sub-zero to over 800F, Malleable delivers more strength per dollar than any other metal, ferrous or non-ferrous. In addition, your products will profit from Malleable's exceptional machining ease and uniformity, and the efficiency of the casting process.



Eight years of service at 900F without a failure! That's the history of these pearlitic Malleable conveyor chains carrying aluminum billets through a furnace. Similar Malleable chains have been subjected to temperatures as high as 1300F in sheet steel normalizing furnaces for years without failure.

Subjected to dynamic stresses at temperatures from 500 to 750F, these pearlitic Malleable truck and bus diesel engine pistons commonly provide more than 40,000 hours of service . . . over 1,000,000 miles!

Free Engineering Aid — To help you more exactly evaluate the possibilities of producing better products at lower cost with Malleable castings, send for *Data Unit 108—Elevated Temperature Characteristics of Malleable Iron Castings.* Your copy is available from any foundry listed below, or Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

For Quality and Economy... Use MALLEABLE

For Service In Your Area Contact...

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Eastern Malleable Iron Co., Naugatuck
New Haven Malleable Iron Co., New Haven 4

DELAWARE
Eastern Malleable Iron Co., Wilmington 99

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Chicago Malleable Castings Co., Chicago 43
Moline Malleable Iron Co., St. Charles
National Mall. and Steel Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Albion Malleable Iron Company, Muncie Division, Muncie
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National Mall. & Steel Castings Co., Indianapolis 22

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MASSACHUSETTS
Belcher Malleable Iron Co., Easton

MICHIGAN
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Central Fdry. Div., Gen. Motors, Saginaw

MINNESOTA
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Westmoreland Mall. Iron Co., Westmoreland

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Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
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Texas Foundries, Inc., Lufkin

WEST VIRGINIA
West Virginia Mall. Iron Co., Point Pleasant

WISCONSIN
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Kirsh Foundry Inc., Beaver Dam
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Milwaukee Malleable & Grey Iron Works, Milwaukee 46

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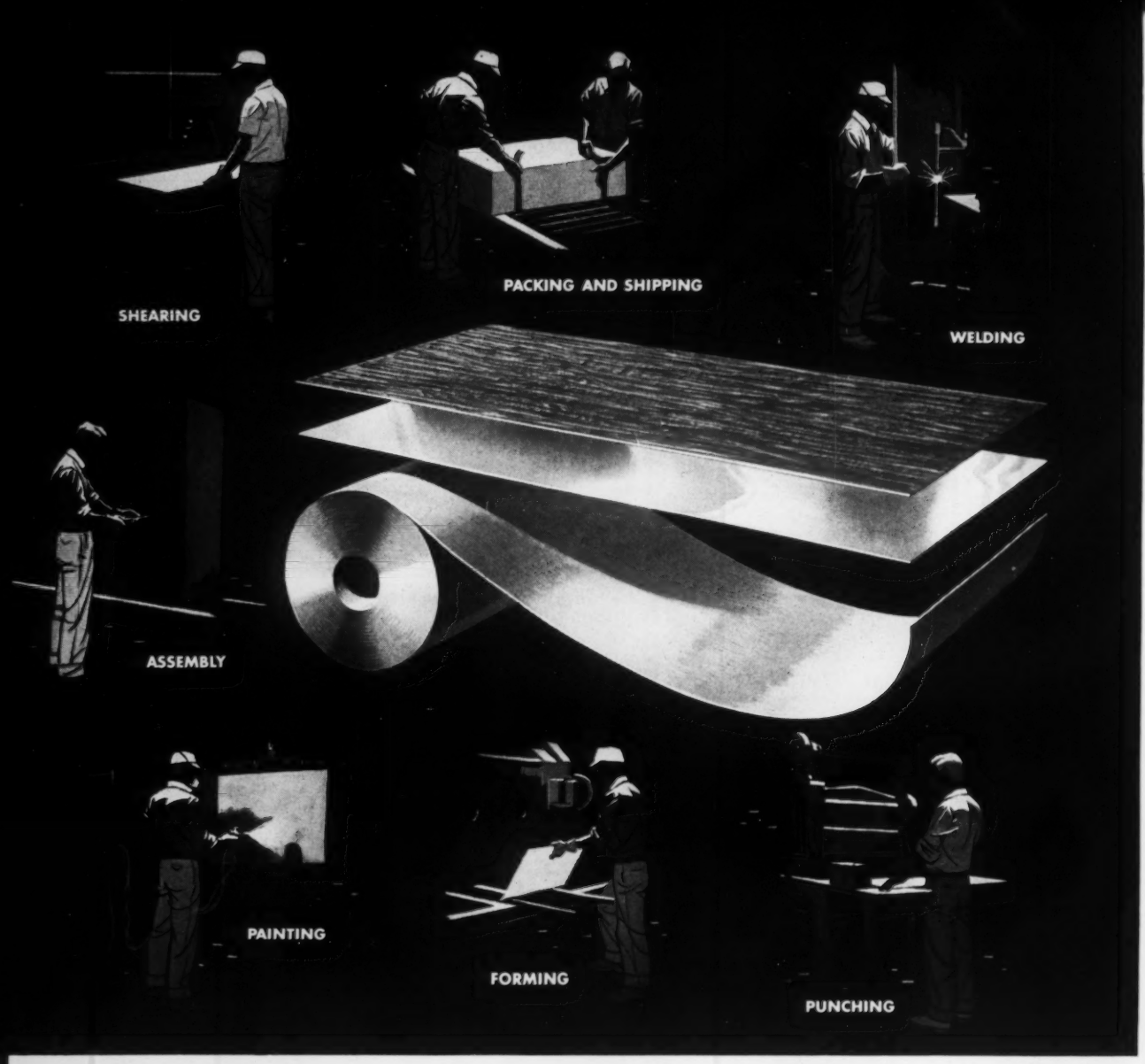
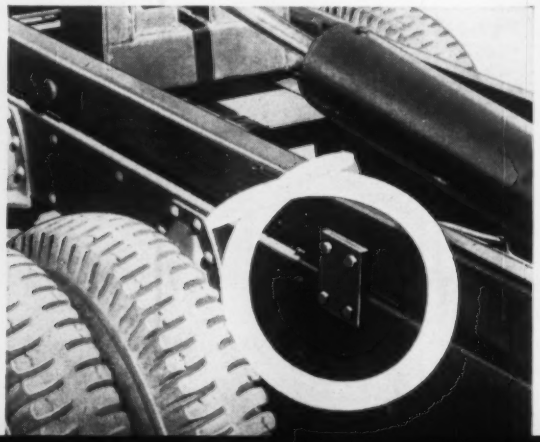


MACHINING HIGH-STRENGTH METALS: Republic Titanium was cut, ground, tapped, spot welded, heat treated, and hand forged by the Crane Co., Chicago, Ill. Parts produced were valve components—lower stems, disc stem rings, and disc and stem ring pins—used in Freeport Nickel Company's new $119,000,000 nickel-colbalt processing facilities. Crane reports, Republic Titanium permitted close-tolerance machining with considerably fewer rejects. Call your Republic representative, or send coupon for data.

REPUBLIC NYLOK NUTS hold tight, resist vibration, and grip with a positive lock to anchor dump bodies to the chassis at the Heil Company, Milwaukee, Wisconsin. NYLOK Nuts stay tight in any position—seated or not. Easy to apply manually or automatically. Can be used over and over again. Check your products for application where NYLOK Nuts can do the job better. Send coupon for complete Republic NYLOK fastener information today.



REPUBLIC SHEET STEEL FABRICATION "KNOW-HOW"

Solves Manufacturing, Assembly, Delivery problems

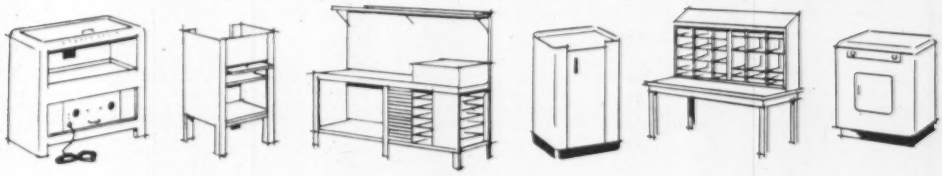
Republic's Berger Division complete sheet steel fabrication "know-how" may be the answer in giving your products a new look, new market acceptance, new sales potential.

Berger has experienced engineers and craftsmen, and the facilities and abilities to manufacture sheet steel products from galvanized steels, stainless steels, and the new vinyl coated sheet steels.

Berger offers a well rounded stock of tools and dies, modern assembly lines for shearing, punching, forming, finishing, and painting. Standard and special arc, spot, and gas welders designed for production line assembly. Tumbling barrels and plating equipment. Grinders and sanders.

Finest finishing facilities, including Bonderizing and electrostatic paint spray equipment. Finishing conveyors through spray booths, dip tanks, and baking ovens. Automatic material handling equipment. Completely mechanized crating department with conveyor line carton-packaging facilities.

Let Berger Division engineers work with you in designing and developing your product. Use Berger facilities to solve manufacturing and delivery problems. For complete details, contact Berger's Contract Manufacturing Department, today!

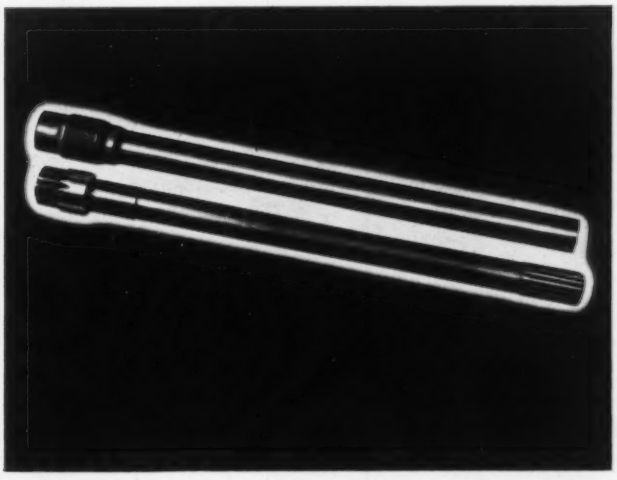


FABRICATING GALVANIZED STEELS... STAINLESS STEELS... VINYL COATED SHEETS

REPUBLIC DIE-FORM BLANKS REDUCE COSTS because the Die-Form Blank (above) closely approximates the completed part (below), scrap losses are negligible and machining is held to a minimum. Die-Form is a new method of cold forming hot rolled carbon, alloy, or stainless steel bars into multi-diameter blanks ready for final machining. Handling costs for raw material and scrap disposal are greatly reduced. Production rates are increased. Write for data.

REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products



REPUBLIC STEEL CORPORATION
DEPT. ME-9937
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please send more information on the following products:

☐ Republic Contract Facilities ☐ Have representative call
☐ Republic Titanium ☐ Republic NYLOK® Fasteners
☐ Republic Die-Form Blanks

Name_____ Title_____

Firm_____

Address_____

City_____ Zone____ State_____

For more information, turn to Reader Service card, circle No. 443

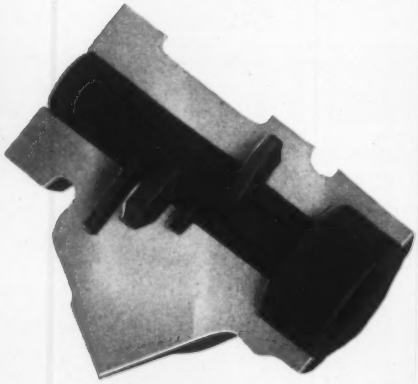
Can You Use BETTER Gray Iron Castings?

Eaton's Continuing Research and Development Programs Assure You the BEST—Engineered to Your Individual Needs

EATON PERMANENT MOLDING

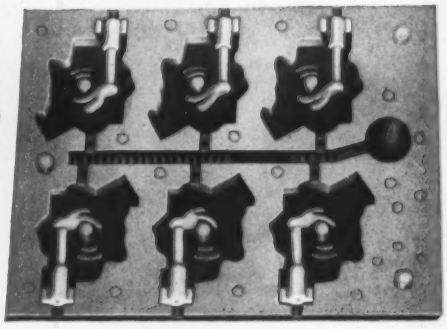
Because of the denser, non-porous, homogeneous structure, Eaton Permanent Mold Castings meet critical quality requirements. The finer dispersion of graphite provides a better material where free machinability and accuracy are essential in critical machining operations. Eaton annealed gray iron castings are available in sizes from one tenth of a pound to fifty pounds.

EATON SHELL CORING



The Eaton process of Shell Coring in permanent mold and shell molded castings provides better internal surface finish and higher dimensional accuracy. Where more than ordinary quality and control of contour are required, the Eaton process offers distinct design advantages and greater uniformity in intricately cored sections.

EATON SHELL MOLDING



Eaton Shell Molding provides more closely controlled metallurgy and hardness for applications requiring pearlitic structures, close dimensional control, and complex designs and contours. Eaton Shell Mold Castings require less machining and finishing, with resulting savings in material, tooling, and shipping.

Send for Illustrated Descriptive Literature

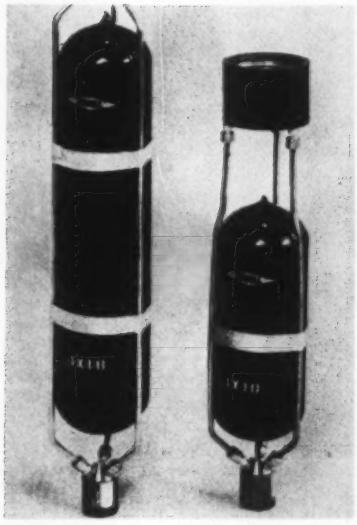
EATON

FOUNDRY DIVISION
MANUFACTURING COMPANY
VASSAR, MICHIGAN

For more information, turn to Reader Service card, circle No. 389

THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING



NEW WAY TO TICKLE A "TRICKLE" WELL

For some centuries now, great bangs around the globe have borne witness to man's sometimes happy faculty for putting to work the phenomenon we call "explosion."

Now we are finding ways to make use of *im*plosion. And glass is helping us.

Supposing your oil well starts to ooze instead of gush. You take one of the devices shown above and lower it into the well. Fill the hole with fluid and apply pressure. When the psi reach a set level, you get a squoosh and then a whoosh and then—with luck—a gush of oil.

The squoosh signals an implosion; the whoosh, a counteracting explosion in the fluids. Working together, the two forces develop pressure waves up to 20,000 psi, usually enough to fracture the surrounding strata and to stimulate the flow of any oil present in the formation.

The service using these capsules is called Rockshock;* it was developed and is offered by Dowell Division of The Dow Chemical Company. The capsules are made from PYREX® brand glass blanks which we supply. The capsules are evacuated to extremely low pressures.

We make the composition of the glass blanks and their wall thicknesses to exactly the right specifications so that the capsules will implode at specified pressures.

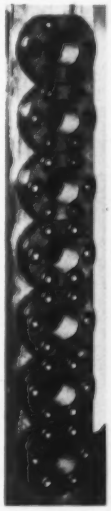
We make the glass so that it will *dice* when it implodes, disintegrating instantaneously to pieces small enough to pass through valves and pumps without damaging them.

At the same time, we make the glass sturdy enough so that you can handle the capsules used in Rockshock above ground with as much safety as glass bottles.

Dowell can tell you more about Rockshock. They are in Tulsa, Oklahoma. We can tell you more about the marvels of glass . . . say, in our Bulletin B-83, titled "Properties of Selected Commercial Glasses." We are in Corning, New York, and can be reached by coupon.

*Dowell Service Mark

STEAM GAUGE THAT WORKS LIKE A TRAFFIC LIGHT



When you see red, you're looking at live steam. When you see green, you're looking at water.

It's as simple as that with this new Multi-Port gauge from the Diamond Power Specialty Corporation.

Like so much that's simple, this takes a fairly complicated system of optics, for which we supply the glass.

Like so much that's complicated, this optical system takes advantage of a simple fact, namely, water and steam have different refractive indexes.

At the rear of the gauge a group of sealed-beam lamps (we probably made the glass for these, too!) throw light on two colored pieces of glass. One is red, the other is green. If the light then passes through steam, only the red portion gets through to the viewing port. Vice versa for water. If the water level falls half way up a port, you see both red and green with a sharp line of demarcation at exactly the right level.

You can see the gauge in the dark. Since light has the swiftest of all movement, there is absolutely no time lag when the steam level changes.

Aside from its optical properties, the glass we provide has to take the thermal shock of live steam, the corrosive environment of steam and water, and pressure up to 3000 psi.

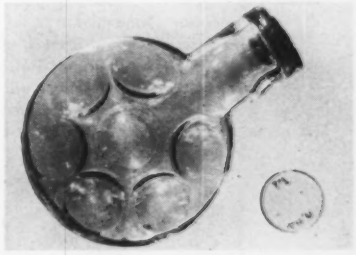
Actually, these are simple conditions for us to meet, as you'll discover, if you ever have occasion to put one of our glasses to work.

Bulletin IZ-1, "Designing with Glass for Industrial, Commercial, and Consumer Applications," can help you spot such occasions. The coupon will fetch you a copy.

WHY EYEGLASS LENSES DON'T COME IN BOTTLES ANY MORE

In 1912 this flask was a marvel of mass production. With just a few good puffs one of our glassblowers could produce blanks for a dozen or more eyeglass lenses.

Now look at the lens blank in the corner of the picture. It has the stamp of technology all over it. Code letters and numbers. Nicely finished edges. Each one like the other.



Now we have machines to stamp out lens blanks . . . even bifocal lens blanks . . . by the millions without a glassblower drawing breath.

A perfect example of our willingness to sacrifice the romance of handcrafting to the sheer economy and efficiency of machinecrafting whenever it will benefit our customers.

The only interest we expect you might have in all this is in this simple fact: we have *two* kinds of versatility to sell. The versatility of glass itself. The versatility of methods in manufacturing from glass.

We can cast giant mirrors and windows for radioactive cells, blow delicate bubbles for lab ware, press or roll great masses for items needed in large quantities in a hurry . . . in short, we can put to work practically every manufacturing method known to man to put your product in glass.

"This Is Glass" is a booklet that tells more about these methods and glass itself. It's in the coupon.

CORNING MEANS RESEARCH IN GLASS

CORNING GLASS WORKS, 50 Crystal St., Corning, N. Y.

☐ B-83; ☐ This Is Glass; ☐ IZ-1

Name..... Title.....

Company.....

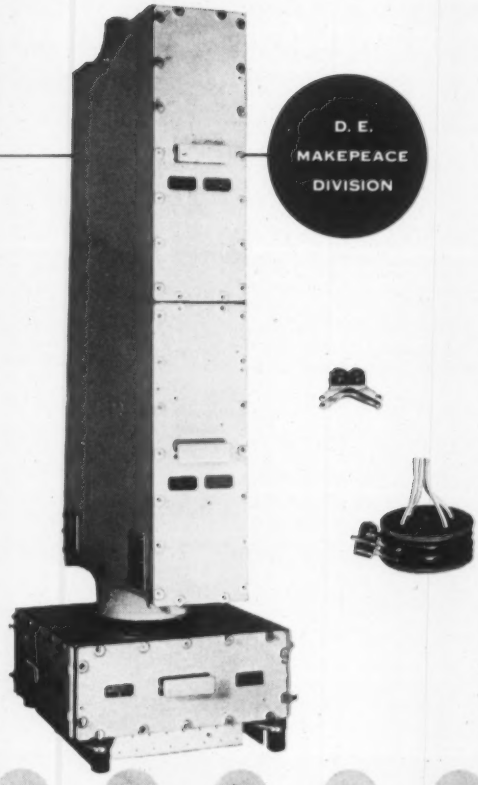
Street.....

City..... Zone..... State.....

For more information, turn to Reader Service card, circle No. 320

recognized leadership in the design and manufacture of slip ring assemblies.

D. E. MAKEPEACE DIVISION



The country's leading producers of electrical and electronic equipment look to Makepeace for the design and manufacture of slip ring assemblies.

Slip ring design for particular applications depends upon the various electrical and mechanical factors involved. Thus, Makepeace has developed many special alloys and combination of alloys to meet a wide range of requirements. Our engineers and metallurgists are thoroughly qualified in this specialized field and will be pleased to make recommendations on your particular problem.

Complete facilities are available for the manufacture of slip ring assemblies ranging in diameter from 1" to 48" and larger—for General Purpose, Radio Frequency and Video Ring Circuits, High Speed Instrumentation, High Voltage Ring Circuits and Power Pulse Slip Rings. A slip ring data file is available—write for your copy.

D. E. MAKEPEACE DIVISION • PINE & DUNHAM STREET
ATTLEBORO, MASS.

a complete range of brush materials for printed circuit applications.

BAKER CONTACT DIVISION

Because the correct choice of contact materials for use on printed circuits is wholly dependent upon such factors as type of circuit, circuit function and mechanical design, the final selection of materials is generally obtained on an empirical basis.

Baker engineers and metallurgists are prepared to offer very broad, specialized experience, together with extensive records of performance data that can be extremely useful to you. They will be pleased to assist in resolving your particular problems in this field.

Baker-developed alloys and powdered metal products meet the full range of brush material requirements for printed circuit applications. Complete facilities are available here for reliable design and manufacture. Send for literature.

BAKER CONTACT DIVISION • 207 GRANT AVE., E. NEWARK
HARRISON P. O., N. J.

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PROMPT PRECIOUS METAL SCRAP RECOVERY SERVICE • ENGELHARD PROCEDURES RECOVER

AMERICAN PLATINUM & SILVER DIVISION

a simplified mirror-bright silver plating process for electrical and electronic components

Here is the most efficient, simple procedure to protect electrical electronic and lamp components with a mirror-bright silver finish—through a complete range from flash to heavy deposit. The procedure is easy, economical and non-critical —with little or no polishing required. Silva-Brite is a clear, water-white solution, enabling the operator to observe work as it is being plated. Uniformly good results are attained with current densities ranging from 10 to 40 amperes per square foot. Normal room temperature operation minimizes fumes and tendency toward bath decomposition. Send for descriptive data together with detailed plating procedures.

AMERICAN PLATINUM & SILVER DIVISION
231 N. J. RAILROAD AVENUE, NEWARK, N. J.

ENGELHARD
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EXECUTIVE OFFICES.
113 ASTOR STREET · NEWARK 2 NEW JERSEY

AMERSIL QUARTZ DIVISION

look to Amersil for all high purity fused quartz requirements.

Amersil manufactures and fabricates high purity fused quartz for ultraviolet transmission applications, laboratory ware and production equipment. These products include standard apparatus, plain tubing in many intricate fabrications, crucibles, trays, cylindrical containers and piping in a full range of sizes up to 25" in diameter. Ingots and plates are available in general commercial quality as well as in special optical grades. Amersil engineers are also prepared to assist in developing fused quartz and silica equipment for special requirements. Send for literature.

AMERSIL QUARTZ DIVISION • 685 RAMSEY AVENUE
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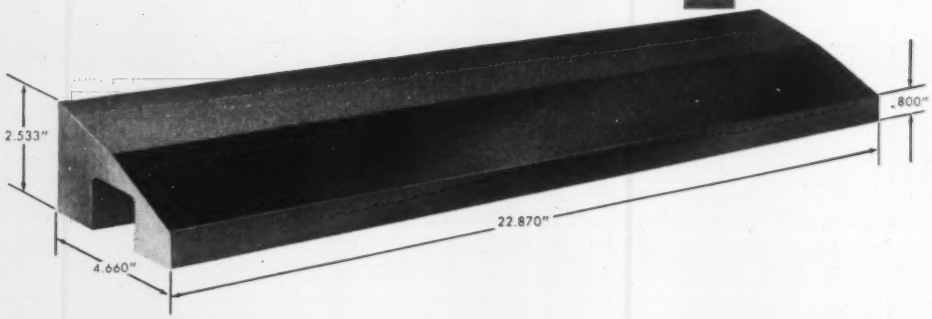
GOTA • ENGELHARD INDUSTRIES S.A.R.L., PARIS • ENGELHARD INDUSTRIES A/S, COPENHAGEN • GLOVER & GOODE PTY., LTD., MELBOURNE • ENGELHARD INDUSTRIES, K.K., TOKYO • ENGELHARD INDUSTRIES, PTY., LTD., MELBOURNE • ENGELHARD INDUSTRIES, LTD., ZURICH • INDUSTRIE ENGELHARD S.P.A., ROME • GUILIANO STACCIOLI—METALLI PREZIOSI S.P.A., ROME • INVERSIONES EN INDUSTRIES NACIONALES, S.A., BOGOTA. **ASSOCIATED COMPANIES:** KALIE-CHEMIE-ENGELHARD KATALYSATOREN G.M.B.H., HANOVER

100% OF ASSAYED PRECIOUS METAL CONTENT • IRVINGTON-BAKER REFINING DIVISION

For more information, turn to Reader Service card, circle No. 418

Maximum Density in Limited Space

WITH FANSTEEL 77 METAL



HERE'S 120 lbs. PACKED INTO ONLY 0.109 CU. FT.

Fansteel 77 Metal—non-magnetic, easily machined and joined to other metals. No special handling required—it is non-toxic, non-radioactive. Used extensively in applications requiring maximum density in the smallest possible space: shields, counterweights for aircraft control parts, rotors, governors, flywheels, vibration dampers. Fansteel 77 Metal is also available in bars, rods, rings, disks and special shapes.

When you need to pack a lot of weight in a small space to lick any problem . . . for radiation shielding, vibration dampening, counter-balancing, etc . . . design around Fansteel 77 Metal. Your part will take up as little space as possible while providing the service required.

Whether you need extra density for shielding purposes . . . or just extra weight, Fansteel 77 Metal will do the job . . . and do it in less space because it's twice as heavy as steel, 50% heavier than lead, much stronger than cast iron.

If your problem requires the density of 77 Metal in a large area, Fansteel now has the facilities to provide finished parts or the metal in ingot or any form required. For example, the radiation shield shown above is 22.870" long x 4.660" x 2.533" x 0.800". It started as a blank which was designed to provide the minimum loss in both metal and machining time. This large blank was produced in the Fansteel plant by powder metallurgy methods . . . pressed, sintered, and then machined to customer's specifications.

Call in your Fansteel representative or send details to Metals and Fabrication Division,

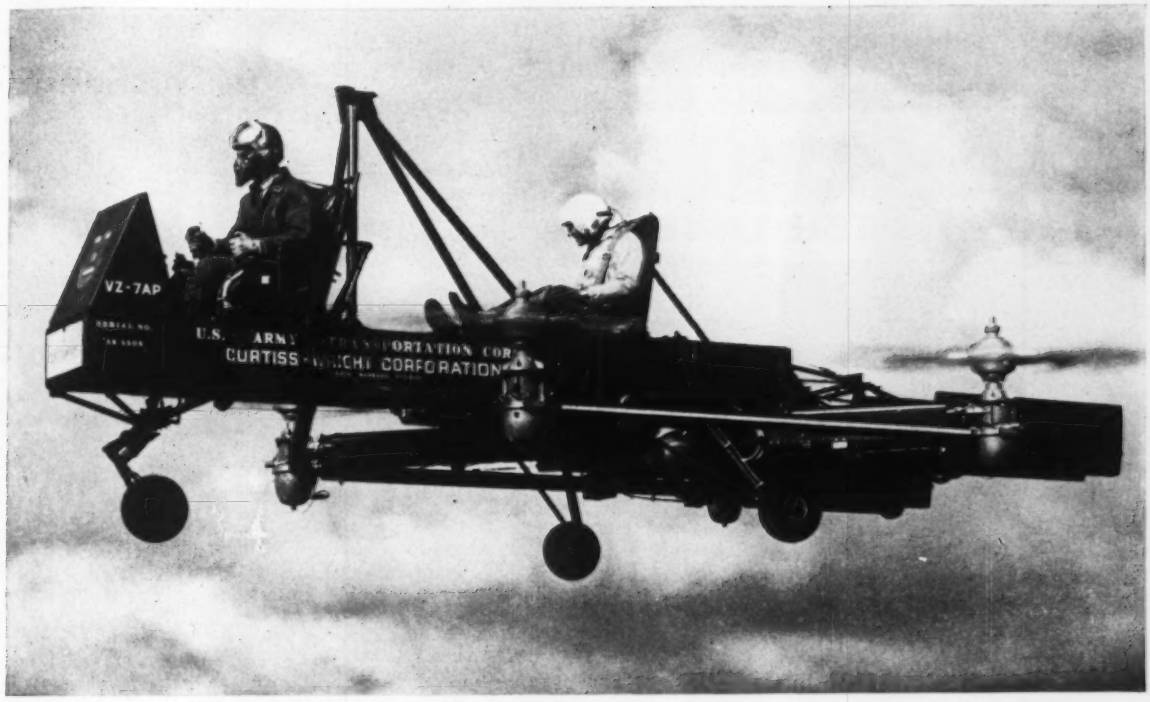
FANSTEEL METALLURGICAL CORPORATION
North Chicago, Illinois, U.S.A.

Write for latest Booklet on Fansteel 77 Metal

FANSTEEL
HIGH TEMPERATURE METALS

K607

For more information, turn to Reader Service card, circle No. 450



RESEARCH AERIAL PLATFORM will have high degree of civilian utility. Transmission system, whose component parts act as power units and structural members, employs 4340 and 4620 nickel alloy steels for shafts and gears.

Aerial platform's unique transmission system uses two nickel alloy steels—4340 and 4620

This experimental aircraft combines the maneuverability of a helicopter with the load-carrying capacity of a truck.

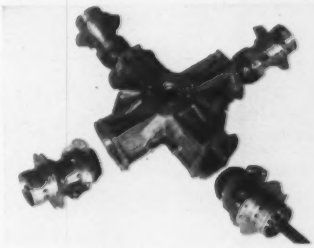
The platform is built around a unique transmission system whose components act as both power units and structural members. Designed jointly by Curtiss-Wright Corporation and Sargent Engineering Corporation, its builders, the platform uses a 400hp gas turbine engine to power four 2-blade propellers through a central gearbox arrangement.

For the gears, the designers specified carburized and hardened AISI Type 4620 nickel alloy steel in the central gearbox and in each of the propeller gearboxes. At every running speed, case-hardened gears of 4620 alloy steel withstand friction and wear. What's more, 4620 gear cores are tough enough to absorb any sudden shock-loads that may occur during flight.

For the propeller shafts, the specifications called for AISI 4340 nickel alloy steel, heat-treated to 30-35 Rockwell C. This versatile through-hardening steel provides exceptional toughness and fatigue strength, and is noted for its superior machinability at high hardness levels. In addition, AISI 4340 steel develops uniform hardness throughout parts of medium to heavy section, despite variations in section size.

The men who designed the aerial platform couldn't predict all the complex stresses these parts would encounter in operation. They selected 4340 and 4620 because these steels have *proven* their reliability and versatility during many years of service, under a variety of strenuous operating conditions.

Whether or not you, too, are experimenting, 4340 and 4620 offer you the same assurance of reliability . . . plus a way to cut costs by simplifying inventory. These steels are available right off the shelf at your local Steel Service Center. Other nickel-containing steels, providing more specialized properties, are also widely available.



EXPANDED VIEW of central gearbox shows how 4620 nickel alloy steel gears fit into box and drive the four propellers.

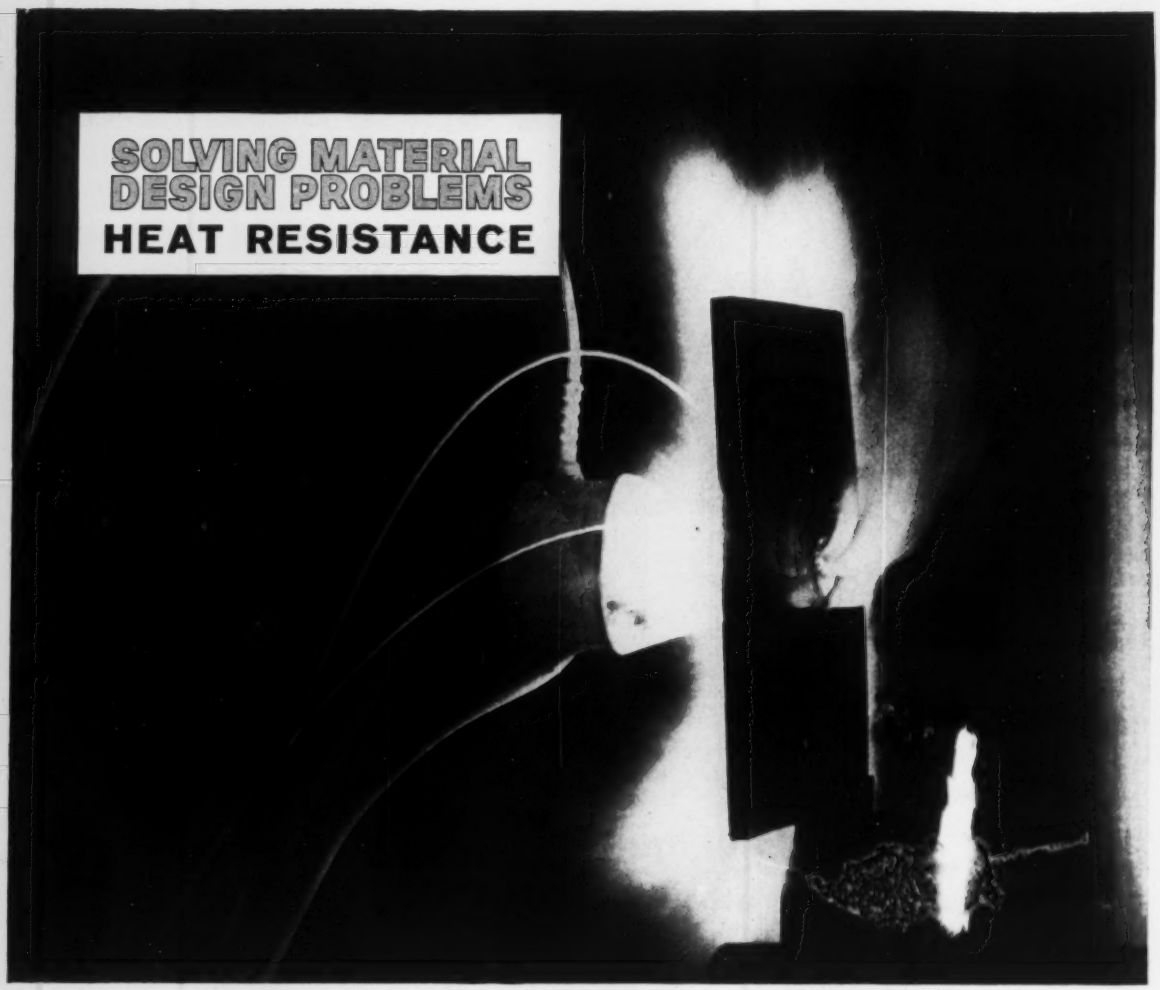
Consider nickel alloy steels for gears, shafts, bearings and other parts you design, order or use. And for information to help you select the right material for your application, just write us.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

NICKEL MAKES STEEL PERFORM BETTER LONGER

SOLVING MATERIAL DESIGN PROBLEMS
HEAT RESISTANCE



A 5000° flame takes ten minutes to penetrate a one-quarter inch piece of CDF's new Dilecto RD-105 laminate. The same thickness of cold-rolled steel is pierced in less than forty seconds.

Molded from graphite fabric impregnated with a heat (ablation)-resistant phenolic resin, new CDF grades RD-105 and RD-115 are being evaluated in solid propellant rocket motors.

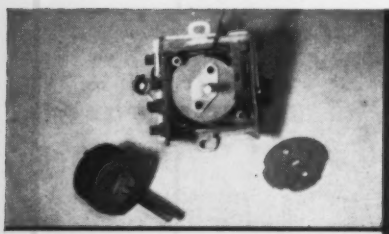
Dilecto laminates are only one family of products from industry's largest selection of non-metallic structural materials and electrical insulations. Vulcanized fibre, silicone rubber and mica, and thermosetting moldings are also supplied by CDF.

CDF can provide both quality and true economy in selecting plastic materials best suited to your needs. Refer to SWEETS PD file or write to us for General Folder 60.

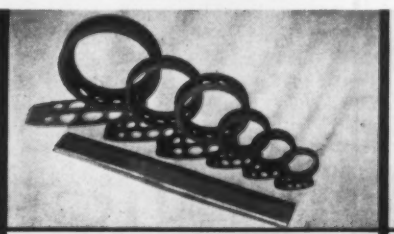
CONTINENTAL-DIAMOND FIBRE

CDF® A SUBSIDIARY OF THE Buhl COMPANY • NEWARK 25, DEL.

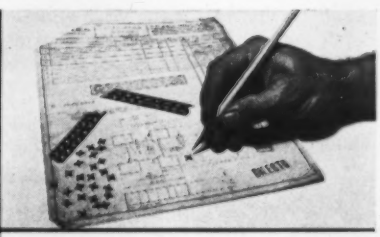
In Canada, 46 Hollinger Road, Toronto 16, Ont.



Moisture-resistant and low cost Dilecto cams for automatic washer and dryer controls.



Dimensionally stable, light weight, oil-resistant Dilecto ball bearing retainer rings.



Easily fabricated paper-base, punching grade Dilecto precision switch insulators.

For more information, turn to Reader Service card, circle No. 325

MR. ENGINEER: HAVE YOU THOUGHT OF NATIONAL GRAPHITE?

"National" graphite is available from stock in a wide variety of sizes ranging from minute particles (powder) to five-ton blocks. Recently, National Carbon produced cylindrical stock 61″ in diameter by 72″ long weighing seven tons, rectangular stock 30′ long by 14″ wide by 12″ thick, and slab stock 120″ long by 47″ wide by 20″ thick. Compare these large shapes with minute pieces, many of which will fit in the palm of your hand, and you'll realize the range of sizes available for your design applications.

This high-temperature material with its unusual combination of properties can be supplied either as plain or machined pieces. Whatever your needs, let National Carbon Company quote the job. For details on sizes and grades of graphite available—whether round, square or rectangular—write for CATALOG SECTION S-5950. Address: National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

"National" and "Union Carbide" are registered trade-marks for products of

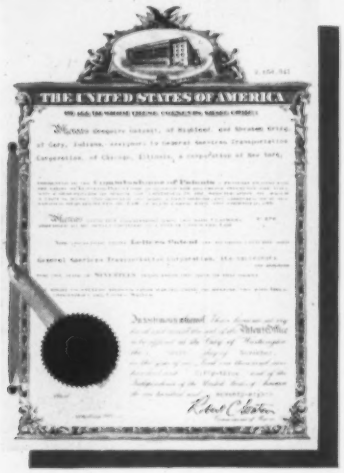
NATIONAL CARBON COMPANY

UNION CARBIDE

For more information, turn to Reader Service card, circle No. 404

a Reminder

to those who use chemical nickel alloy plating:



There is only ONE

Kanigen®

and 29 patents prove it

There are no substitutes for Kanigen—no other process that applies a hard, corrosion-resistant nickel alloy coating without the use of electricity as Kanigen does.

With Kanigen, you can plate anything from a small relief valve to a 20,000 gallon tank car with a virtually non-porous, uniform coating.

How can you be sure of getting Kanigen? Only one way—by calling General American or one of its licensees. For further information write:

Kanigen Division

GENERAL AMERICAN TRANSPORTATION CORPORATION

135 South LaSalle Street
Chicago 3, Illinois
Offices in principal cities

KANIGEN GENERAL AMERICAN

LICENSEES

INDUSTRIAL KANIGEN CORPORATION
1421 Park Avenue
Emeryville, California

KEYSTONE CHROMIUM CORPORATION
1095 Niagara Street
Buffalo, New York

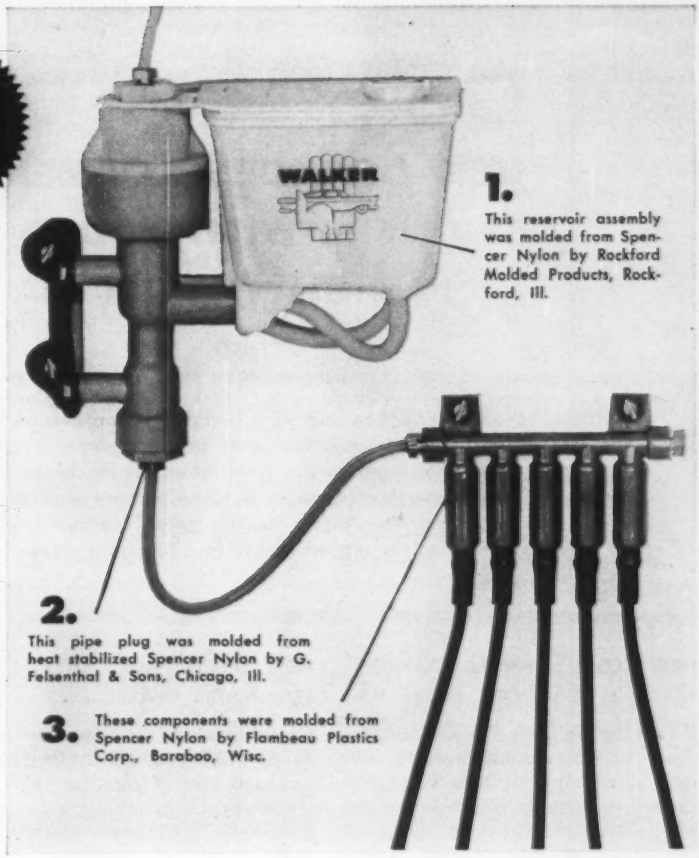
KEYSTONE METAL FINISHERS, INC.
22 Raydol Avenue
Secaucus, New Jersey

For more information, turn to Reader Service card, circle No. 397

Spencer Nylon
used for

Award-Winning Automatic Lubricating System

Spencer Nylon used extensively in Walker Automatic Lubrication System awarded first place for selection and quality of materials.



1. This reservoir assembly was molded from Spencer Nylon by Rockford Molded Products, Rockford, Ill.

2. This pipe plug was molded from heat stabilized Spencer Nylon by G. Felsenthal & Sons, Chicago, Ill.

3. These components were molded from Spencer Nylon by Flambeau Plastics Corp., Baraboo, Wisc.

When Materials in Design Engineering recently announced the winners of their annual competition for the best use of materials in product design, a first place was awarded to Walker Manufacturing Company of Racine, Wisc.

Significantly, Spencer Nylon was used extensively in the award-winning Walker Automatic Lubrication System. Many materials were studied for use in the system. Spencer Nylon was selected because it could satisfy these six important conditions:

1. **Temperatures ranging from —25° to 225° F.**
2. **Contact with mineral lubricants.**
3. **Operating pressures ranging from 40 to 90 psi.**
4. **Good processability.**
5. **Ability to mold to close tolerances.**
6. **Low Cost.**

You, too, can benefit from Spencer Nylon's versatility and wide range of properties. For complete information on how Spencer Nylon can help you, call your Spencer representative or contact Spencer Chemical Company at address below.

*Spencer Chemical Company markets Spencer Nylon, from which nylon parts are molded. Spencer "Poly-Eth" Polyethylene and Spencer "Poly-Pro" Polypropylene. "Poly-Eth" and "Poly-Pro" are registered trademarks of Spencer Chemical Company.

SPENCER®

SPENCER NYLON

SEE OUR CATALOG IN SWEETS PRODUCT DESIGN FILE

OR WRITE FOR COPY

SPENCER is also a prime supplier of

Poly-Eth Polyethylene

POLY-PRO POLYPROPYLENE

SPENCER CHEMICAL COMPANY, DWIGHT BUILDING, KANSAS CITY 5, MISSOURI

For more information, turn to Reader Service card, circle No. 441

DOW | *Now in magnesium and aluminum*

NEW DOW DEVELOPMENTS PROVIDE DESIGNERS WITH ADDED ADVANTAGES IN LIGHTWEIGHT MAGNESIUM

Lightness, ease of fabrication and other features of magnesium contribute to improved designs for many products—from airplanes and missiles to luggage . . . from industrial machinery to cameras. Now, new developments by Dow provide greater design flexibility than ever before—in fabricated components you require, in materials and processes to facilitate your plant's operations.

New sheet is bent without heated dies.

NEW CLOSE SHEET TOLERANCES HELP SOLVE WEIGHT PROBLEMS

When the design problem is stress distribution versus weight, the new, closer magnesium sheet tolerances available from Dow upon special request offer a real advantage. As shown below, new tolerances are one *half* of standard tolerances. This permits designers to provide for required stress distribution, based on minimum thickness, *without* having to accommodate all the extra weight that might occur with the maximum thickness permissible with conventional tolerances.

Especially useful for aircraft and missile designers, this close tolerance sheet is also suggested for use in air-transported equipment or wherever minimum weight is critical.

COMPARISON OF TOLERANCES

48-inch-wide sheet

Gauge	Close Tolerances	Standard Tolerances
.032"	±.0013"	±.0025"
.040	±.0015*	±.003
.050	±.002	±.004
.063	±.002	±.004
.071	±.002	±.004
.080	±.002	±.004
.090	±.002	±.004
.100	±.0025	±.005
.125	±.0025	±.005
.160	±.004	±.008
.190	±.005	±.010

*For HM21A-T8 .040" close tolerance is ±.002".

NEW SPECIAL BEND SHEET ELIMINATES HEATED DIES

Critical bends can now be easily formed at room temperature — *without heated dies*—using Dow's new AZ31B-O Special Bend Sheet. Without cracking, it bends through an angle of 90° around a mandrel radius as small as two times the nominal sheet thickness. Among many suggested applications are housings for electronics equipment, truck cabs, shipping containers, plus such military uses as maintenance and personnel shelters and housings for ground support equipment.

BEND FACTORS

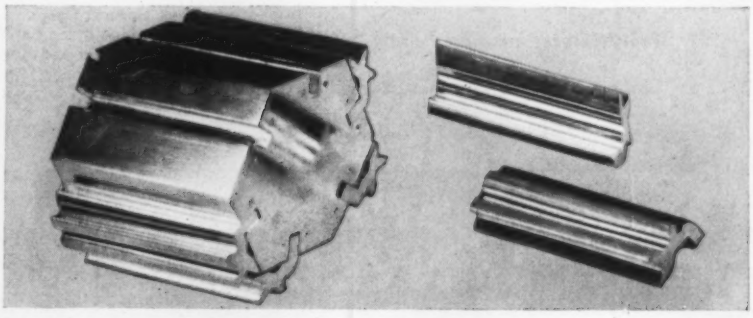
Nominal thickness	Longitudinal bend factor	Transverse bend factor
0.040"–0.100"	2.0	2.5
0.101"–0.190"	2.5	3.0

Tensile yield strength meets Federal Specifications AA-M-44.

PRECISION MAGNESIUM EXTRUSIONS CUT MACHINING COSTS

Dow precision magnesium extrusions provide exact-tolerance finished or semi-finished components and eliminate many costly multiple machining operations. Exacting tolerances are even possible with sharp V's, deep notches, thin slots, sharp serrations, as well as precision diameter tubing. And with precision extrusions, cost of materials is also frequently less because high-property alloys to withstand extensive machining are not needed.

Applications include bearing blocks, impact extrusion stock, parts for business machines, printing furniture, screw machine stock, shaft shear keys, spacers and airfoil configurations.



Exact-tolerance extrusions cut machining costs.

NEW FINISHES BROADEN APPLICATIONS FOR MAGNESIUM

Porcelain enamel, a practically foolproof way to avoid corrosion, can now be applied to magnesium, using a Dow-developed pretreatment to assure adhesion. Suggested applications–display signs, building panels, cooking ware, home appliances, engine parts.

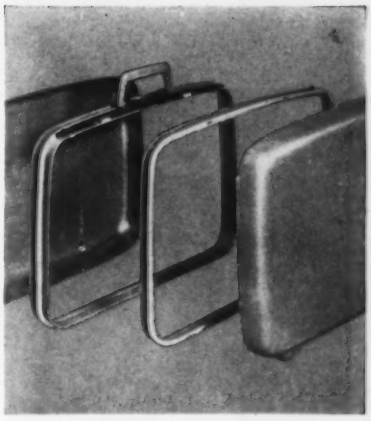
Dow 20 chrome pickle provides a uniform paint-base for casting alloys with high aluminum content.

Dow 21 ferric nitrate bright pickle, as a spray or dip, provides long-lasting protection under clear baking enamels or lacquer.

Clear anodic coating, applied in less than a minute, provides maximum protection under lacquer or varnish, which may be tinted in a wide range of colors.

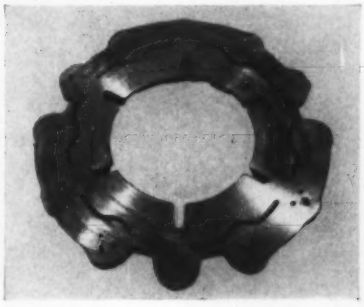
Nickel plating, by immersion instead of electroplating, simplifies processing, improves nickel surface. For electronics equipment, printing plates and cylinders, other surfaces requiring extreme wear resistance.

Vinyl may be laminated before cold-forming magnesium sheets–also bonds to hot-formed shells. For luggage, carrying cases, other applications.



Vinyl-laminate adds sales appeal to carrying cases, luggage.

DOW CASTS MAGNESIUM IN INTRICATE DESIGNS



Casting incorporates tubeless passages.

Cast-in tubeless passageways, thin sections, close tolerances and other intricate designs are all available in castings made in production quantities at Dow's sand and permanent mold foundry.

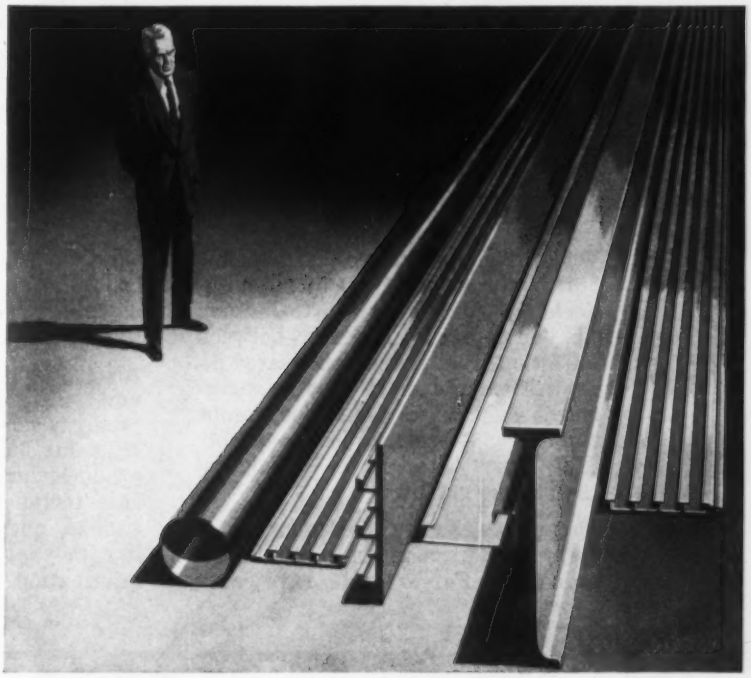
NEW ALLOY ELIMINATES STRESS RELIEF AFTER WELDING

A newly developed Dow alloy for magnesium sheet and plate, ZE10A, containing zinc and rare earth metal, does away with the need for stress relief after welding . . . particularly advantageous in building large structures. Suggested applications – large shipping and storage containers, even tank-trailer bodies. So that designers can take full advantage of this new sheet and plate material, Dow also provides magnesium extrusions in alloys requiring no post-welding stress relief.

VAST PRODUCTION FACILITIES FOR MAGNESIUM AND ALUMINUM

The Dow Metal Products Company offers a new die casting plant, a sand and permanent mold foundry, a fabrication plant plus the huge Madison plant for sheet, plate and extrusions. At Madison, for example, is the giant 13,200-ton press that extrudes king-size sections of magnesium or aluminum–up to 30 inches across and 80 feet long.

For more information about the new magnesium developments shown here, or for help in any design or fabrication problem involving magnesium or aluminum, contact the nearest Dow sales office. Or write THE DOW METAL PRODUCTS COMPANY, Midland, Michigan, Merchandising Department 1053CD8.



King-size extrusions make possible freedom in design.

DOW **THE DOW METAL PRODUCTS COMPANY**

Division of The Dow Chemical Company

For more information, turn to Reader Service card, circle No. 346

MCA FLUX
AND RIMMING STEEL

Very revealing tests may be made for uniformity of analysis of rimming steels, by comparing top to bottom, rim and core, edge to center, between MCA flux treated and non-treated ingots. Elements most readily segregated—sulphur, carbon, phosphorous and nitrogen—are held in remarkably close limits through the economical use of rare earths.

This allows the use of even larger ingots, with its attendant production economies. For example, rare earth additions to larger rimming ingots of 50,000—60,000—70,000 pounds afford a quality and uniformity formerly obtained only in smaller ingots.

Alert engineers and metallurgists are now studying large rimming ingot products made possible by using our MCA flux. MCA, the leading rare earth producer and processor, has valuable technical information on this subject, and will be happy to share it with you. Write today for specific information.

MOLYBDENUM

2 Gateway Center CORPORATION OF AMERICA **Pittsburgh 22, Pa.**

Offices: Pittsburgh, Chicago, Los Angeles, New York, San Francisco
Sales Representatives: Brumley-Donaldson Co., Los Angeles, San Francisco
Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

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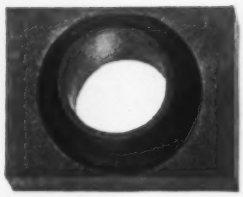
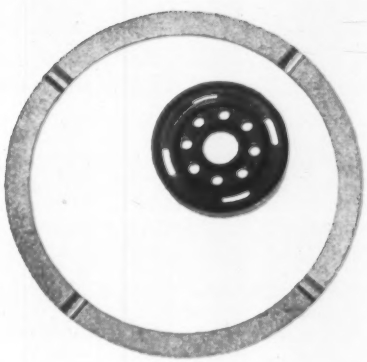
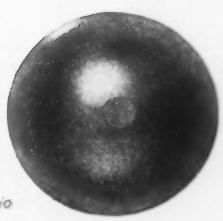
ACCURACY, DURABILITY and ECONOMY are important characteristics of these sintered metal automotive suspension parts by Delco Moraine. Vital components such as these are typical results of close collaboration between Delco Moraine and its customers—an effective liaison that functions from idea through design and development to production. They also confirm Delco Moraine's equally important capabilities for making deliveries in quantity and on time!







DELCO MORAINE

DEPENDABLY MADE parts for industrial progress • Division of General Motors, Dayton, Ohio

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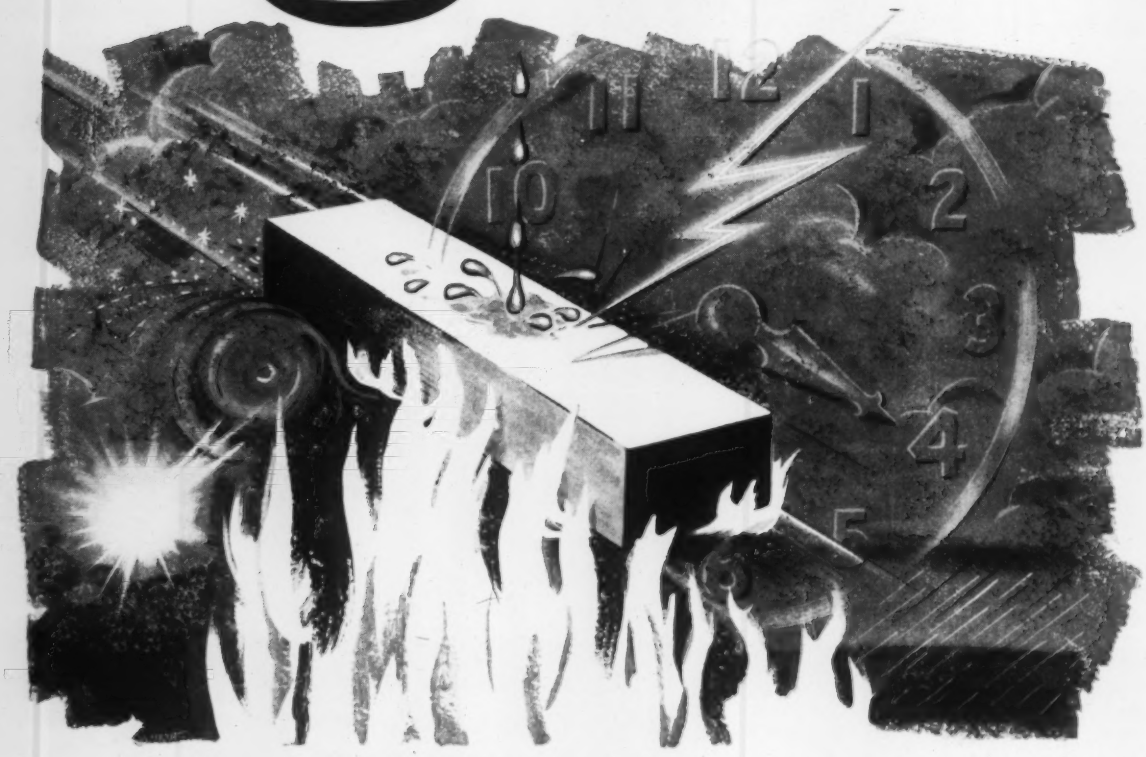
V-R Metals...



where DURABILITY is needed!

Seconds . . . hours . . . years . . . how long must a part last when designed to do a job? Exceptional qualities of V-R metals can help you solve many design problems. Resistance to wear and corrosion . . . high density . . . stability at extreme temperatures . . . rigidity under a given load . . . low coefficient of expansion for greater dimensional uniformity . . . good surface finish obtainable (less than one micron) . . . are some of the characteristics of metals that V-R makes available to the designer.

These properties can be produced in various combinations in sintered or alloyed metals to fill specific performance needs. Parts can be designed in shape and form to give optimum use of the metal.

Use V-R metals in the parts you design to assure durability and dimensional stability. Call your nearest V-R representative or send us the details of your requirements.

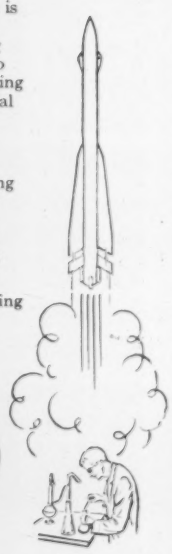
Metals of tomorrow ...TODAY!

Vascoloy-Ramet Corporation is a pioneer manufacturer of refractory metals . . . making its substantial contribution to America's growth by developing special metals with exceptional characteristics to meet the changing needs of industry.

29 years of V-R research, engineering and manufacturing experience . . . covering thousands of application problems . . . have produced the technical know-how built into all V-R products.

This same know-how is working full time, developing new refractory metals, to meet tomorrow's needs.

A-750R



CREATING THE METALS THAT SHAPE THE FUTURE

VASCOLOY-RAMET

852 MARKET STREET • WAUKEGAN, ILLINOIS

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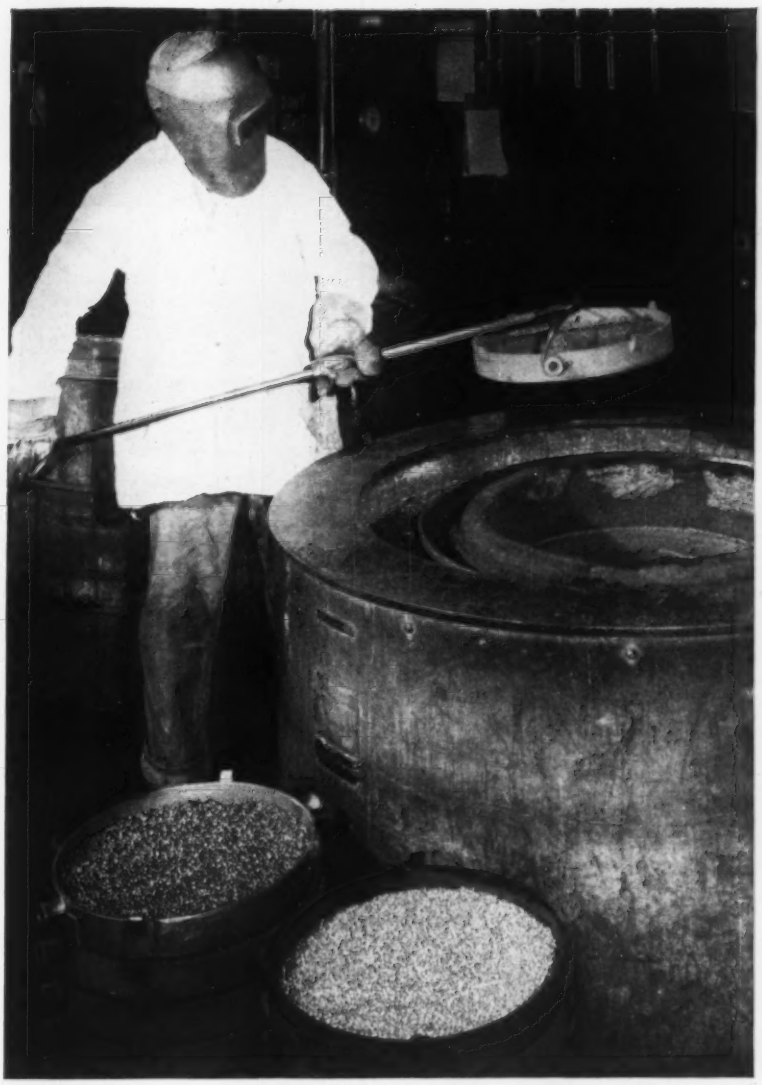

Trays resist carburizing and thermal fatigue. Trays shown here are repeatedly exposed to 1650°F for 4 hours, then water quenched. Made of Type "HX" cast alloy containing 66% nickel, 17% chromium, they display excellent ability to withstand cycling without cracking or severe warping. High nickel alloys such as this are outstanding in their resistance to thermal shock and fatigue.

Through day-in, day-out cycling punishment...

High nickel alloys laugh at high temperatures

Are you looking for a way to outwit thermal fatigue?

Then you'll want to know more about the reliable high temperature alloys available to you.

There are 12 basic types of nickel-chromium-iron alloys that give useful strength and long life to castings subject to a wide variety of potentially destructive environments.

You name the service...temperatures ranging from 1200°F to 2200°F... reducing or oxidizing conditions... nitriding or carburizing atmospheres.

Under all these conditions, the appropriate nickel-containing alloys give good accounts of themselves in everything from trays and racks to tubes and retorts...from baskets and bearings to fans and fixtures.

They come feature-packed. Nickel-containing alloys provide you with heat-resisting castings having good creep strength and high resistance to scaling...thermal fatigue...thermal shock...sigma phase embrittlement.

Making your choice. Of course, the proper selection of an alloy for any specific high temperature job involves consideration of many factors, including:

- Required size and shape of the part
- Type and size of maximum load
- Speed and range of temperature cycling
- Atmospheres and contaminants
- Complexity of design
- Additional fabrication needed

You'll find lots of valuable – and usable – information on the proper selection of casting materials in our new 64-page, illustrated booklet, "Heat Resistant Castings, Corrosion Resistant Castings...Their Engineering Properties & Applications." We'll be glad to send you a copy on request. *Write for it — today.* Just ask for Bulletin A-266.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N.Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

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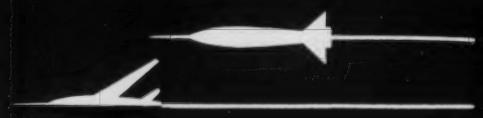
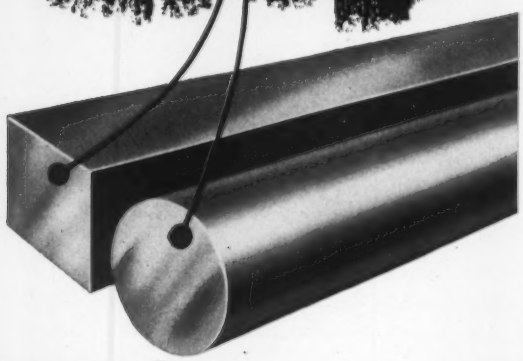


For critical design applications . . .

VAC-ARC* Steels

Latrobe's know-how guarantees reliability

Production know-how gained in making highest quality tool and die steels gives Latrobe an advantage in producing VAC-ARC (consumable vacuum melted) steels to meet critical design requirements. VAC-ARC Steels possess unusual cleanliness, improved ingot structure, and superior mechanical properties.



VAC-ARC Grades Available . . .

APPLICATION	TYPE	GRADE NAME
High Temperature	A-286	Pandex
Bearings	M-50	MV-1
	52100	Regent
Aircraft & Missile	H-11	Dynaflex

Compare!

TYPICAL TRANSVERSE TENSILE PROPERTIES
(8" square billet of Dynaflex)

Property	Mid-Radius		Center	
	Air Melt	Vac-Arc	Air Melt	Vac-Arc
Tensile Strength (psi)	285,000	287,000	285,000	285,000
Yield Strength .2% (psi)	250,000	252,500	245,000	250,000
Elongation %	4	8	2.5	8
Reduction of Area %	10	25	3	24

Call your Latrobe representative . . . or write for literature.

LATROBE Metalmasters / **LATROBE STEEL COMPANY**
LATROBE, PENNSYLVANIA

BRANCH OFFICES and WAREHOUSES:
BOSTON • BUFFALO • CHICAGO • CLEVELAND • DAYTON • DETROIT
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*Latrobe's Trade Name for Vacuum Consumable Electrode Melting

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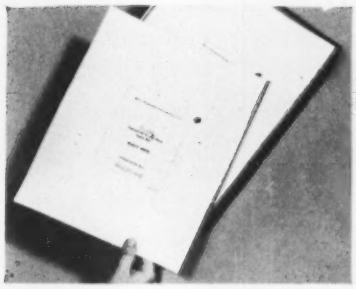
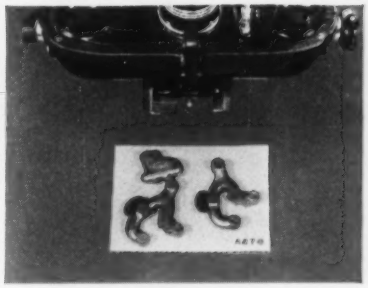


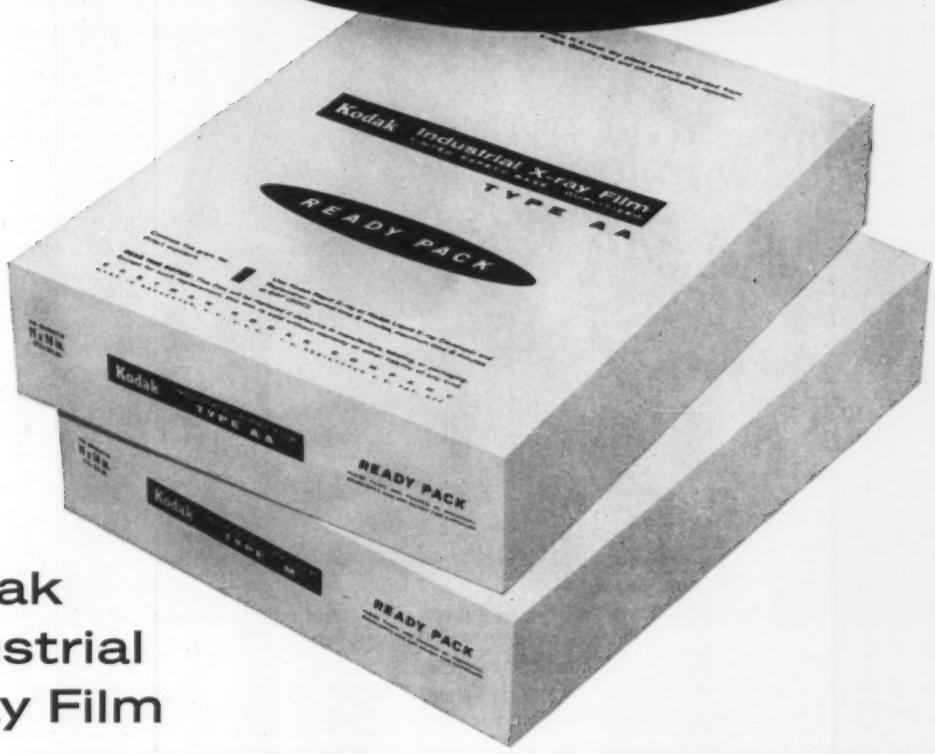
1) No darkroom loading. Ready for exposure as it comes from the box.



2) Just place in position and expose —the film is protected from dust, dirt, light and moisture.

3) In the darkroom, pull the rip strip, remove film, and process.

...NEW!... READY PACK ....



Kodak Industrial X-ray Film

Sealed tight until processed—keeps clean

Very convenient to handle—saves time

Readily available in Type AA and Type M

Here's new convenience when you are inspecting aluminum or magnesium alloys, thin steels, plastic or anything where lead screens are not required.

Kodak Industrial X-ray Film, Type AA and Type M-Ready Pack comes to you with each sheet sealed in a light-tight envelope ready for exposure. A convenient rip strip makes it easy to open in the darkroom.

These films come 75 to a box in sizes 8 x 10, 10 x 12, 11 x 14, 14 x 17. Order them from your Kodak X-ray dealer.

EASTMAN KODAK COMPANY
X-ray Division • Rochester 4, N. Y.

Kodak
TRADE MARK

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Titeflex, Inc., Meets Aircraft Fuel, Lubrication and Hydraulic Line Specifications with

HANDY & HARMAN BRAZE 541

Titeflex operator brazes assembly with torch and hand-fed Handy & Harman Alloy BRAZE 541. *Titeflex is unique in that it makes flexible hose assemblies from raw material to end product—"From End to End, Inside and Out, made RIGHT In Our Own Plant."*

This Springfield, Massachusetts, manufacturer of aircraft and missile fuel, lubrication and hydraulic lines finds that silver alloy brazing with Handy & Harman BRAZE 541 meets rigid operating requirements "all the way down the line."

The tubing and fittings of many of the wide range of assemblies made by Titeflex are 321, 316 and 347 stainless steel and Monel. Brazing is a hand torch, wire and HANDY FLUX operation.

BRAZE 541 is a plastic alloy which melts at 1325° F and flows at 1575° F. Its strength—in shear—at elevated temperatures is 21,500 psi at 500° F and 15,000 psi at 750° F. This alloy's ductility in resisting stress and vibration is very high and its resistance to oxidation and corrosion is equally impressive. The composition of BRAZE 541 is 54% silver, 40% copper, 5% zinc and 1% nickel. It meets AMS Specification 4772.

Aircraft and missile component manufacturers and fabricators are finding—to their and their products' benefit—that Handy & Harman silver alloy brazing is the full and *final* solution to their metal-joining problems. BRAZE 541 is but one of a large family of Handy & Harman alloys, for both low and high temperature applications. We would like to more fully acquaint you with BRAZE 541 and with the advantages that come naturally to silver brazing as a metal-joining (both ferrous and nonferrous) method. Handy & Harman, 82 Fulton Street, New York 38, N. Y.

FOR A GOOD START: BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits . . . includes details on alloys, heating methods, joint design and production techniques. Write for your copy.

Your No. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N. Y.

DISTRIBUTORS IN PRINCIPAL CITIES

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Bridgeport, Conn.
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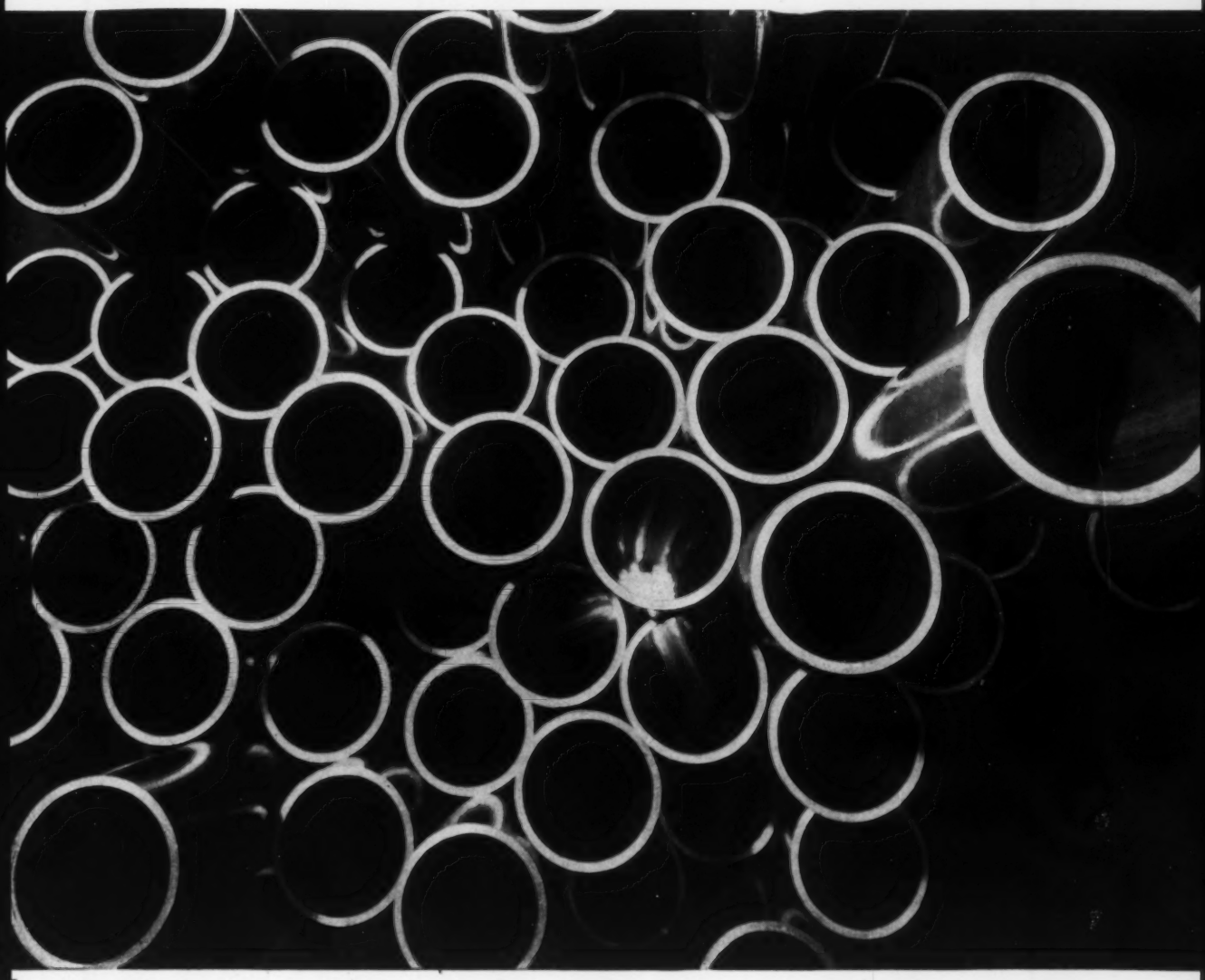
This mark tells you a product is made of modern, dependable Steel.



Look at the dimensional accuracy and smoothness

You can reduce the costs and processing time of parts-making by using USS National Electric-Resistance Welded Mechanical Tubing. It eliminates drilling operations. It lets you replace drills with simple, less expensive boring tools. Mechanical Tubing reduces tool wear and tool changes.

USS National Electric Welded Mechanical Tubing is an ideal load-carrying member. It resists bending stresses equally in all directions and gives you a superior cross section. It absorbs and localizes shock. In torsion, it provides better material distribution. And for a given weight, mechanical tubing withstands more load than other sections.

USS National Electric Welded Mechanical Tubing is available in cold-drawn or hot-rolled sizes $\frac{3}{8}$″ thru $5\frac{1}{2}$″ and in wall thicknesses .035″ to .250″. It can be obtained from National Tube Distributors located throughout the country. They will gladly show you how to use USS National Welded Mechanical Tubing in your next application. *See your USS National Tube Distributor.*

USS and National are registered trademarks

National Tube Division of United States Steel

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors
United States Steel Supply Division
United States Steel Export Company, New York

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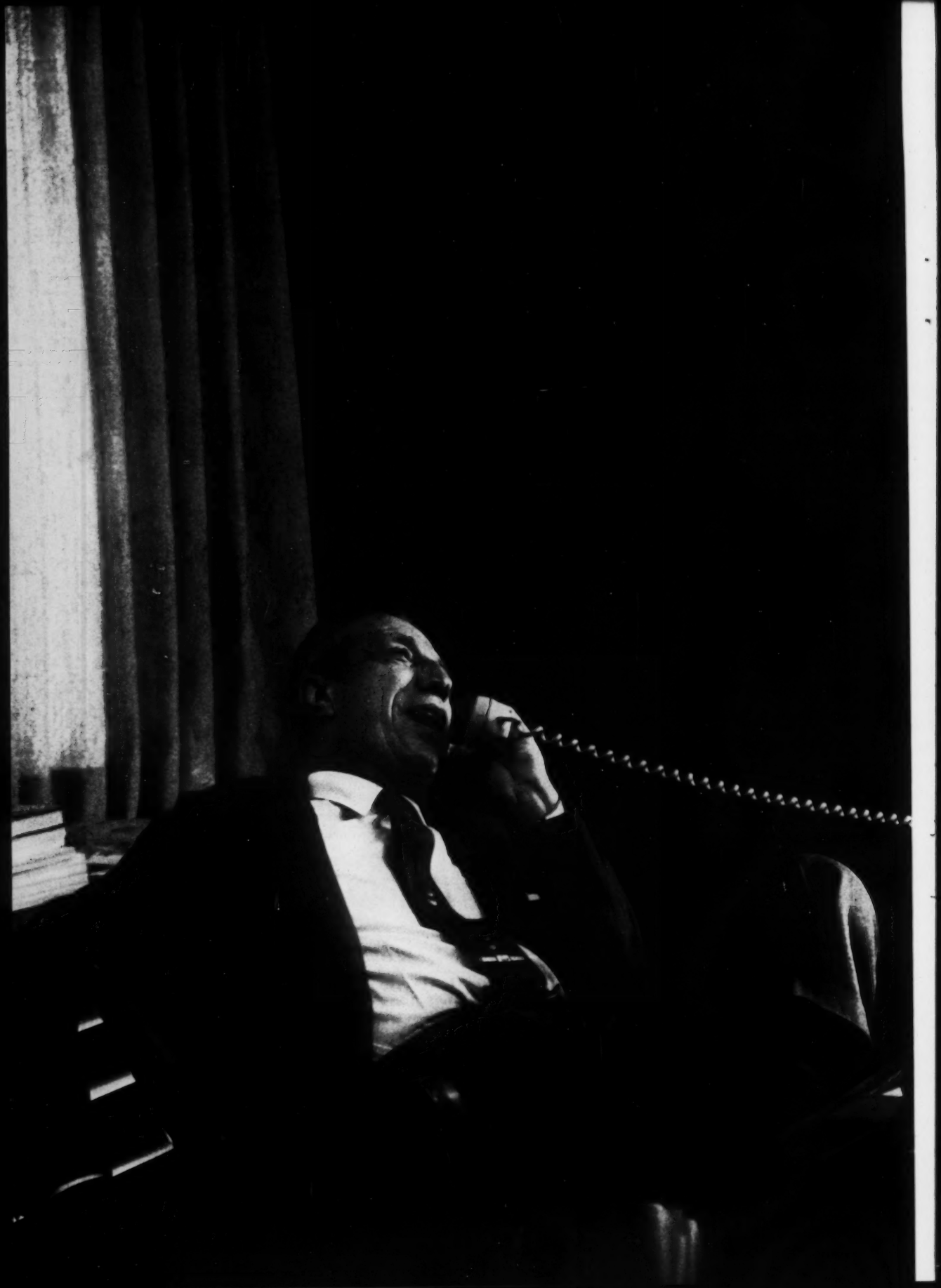

Joe Foster, President, discusses Foster Grant's pioneer experience with bulk handling polystyrene.

"Our Experience in Bulk Handling Polystyrene Can Bring You Carload Savings," says Joe Foster.

As the world's largest manufacturer of sunglasses, we've known the advantages of bulk handling polystyrene since it was first introduced... learned how handling, operating expenses and production overhead could be saved with this unique method of storing polystyrene in quantity.

As an indication of the true economy possible, one customer tells us his Foster Grant designed bulk handling system saves him 40,000 square feet of warehouse space and as much as two cents a pound in handling, in addition to his savings from buying in bulk. And, there are no worries about "heavy construction" warehousing, bag breakage, contaminated resin and high costs of materials handling.

To help you get started in bulk handling, we will be glad to survey your plant operation, suggest plans for efficient silo storage construction and even work on engineering your bulk installation with you. What's more, we'll supply you with a conveying pump and "dri-flo" storage car for as long as six months. This way, you get all the savings from bulk handling polystyrene while your own installation is being assembled.

If you would like to know more about bulk handling polystyrene and the savings in time and money it can mean, just call or write Foster Grant Co., Inc., Leominster, Mass., KEystone 4-6511. We're ready to go to work with your staff right now!

FOSTER GRANT

Your Partner in Plastics Progress

Plants in Leominster, Mass., Manchester, N. H., Baton Rouge, La.
Branch Offices and Warehouses in principal cities

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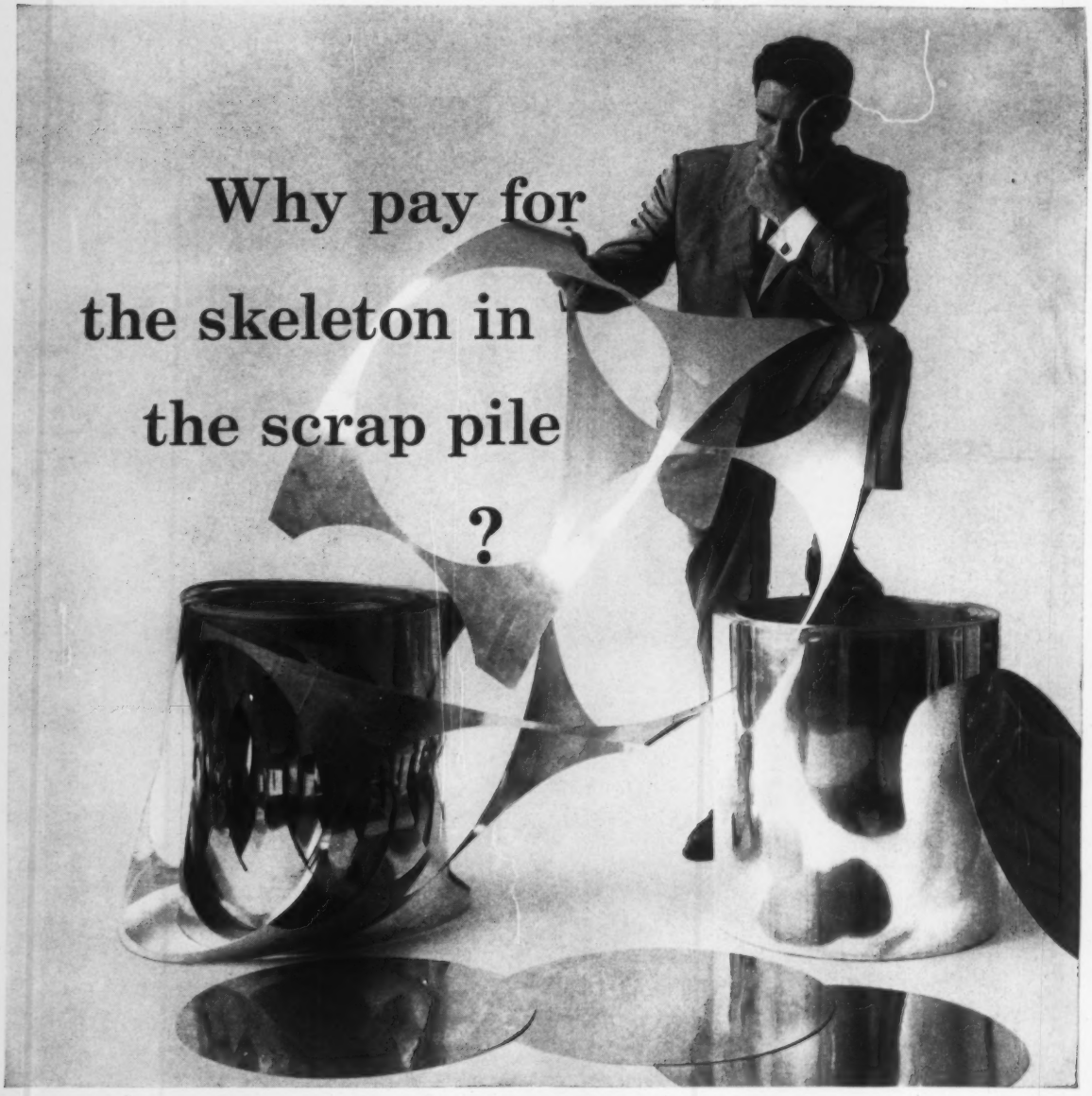

WHEN you stamp your own aluminum circles or any irregular blanks, up to 25% of coil weight ends up as scrap..

You can eliminate this waste—plus labor of shearing and blanking—by buying circles or blanks direct from Fairmont.

Fairmont is *the* source for circles. As a prime supplier of aluminum blanks to *every* utensil maker, Fairmont's 30-year stockpile of dies is unduplicated anywhere. Find out how easily we can fill your requirements from our stock of dies.

Or by blanking from your dies in our plant, we can effect labor, material savings for you.

Other Fairmont benefits: the consistent quality that is a Fairmont tradition . . . individual flash annealing for finer grain structure . . . 100% inspection of every blank.

FIND OUT ABOUT FAIRMONT'S CUSTOM BLANKING SERVICE NOW

A Fairmont engineer will be glad to give you details. Call your local Fairmont office. Or write Vice President, Sales, Dept. 25H, Fairmont Aluminum, Fairmont, West Virginia.

FAIRMONT ALUMINUM

subsidiary of
CERRO
DE PASCO CORPORATION

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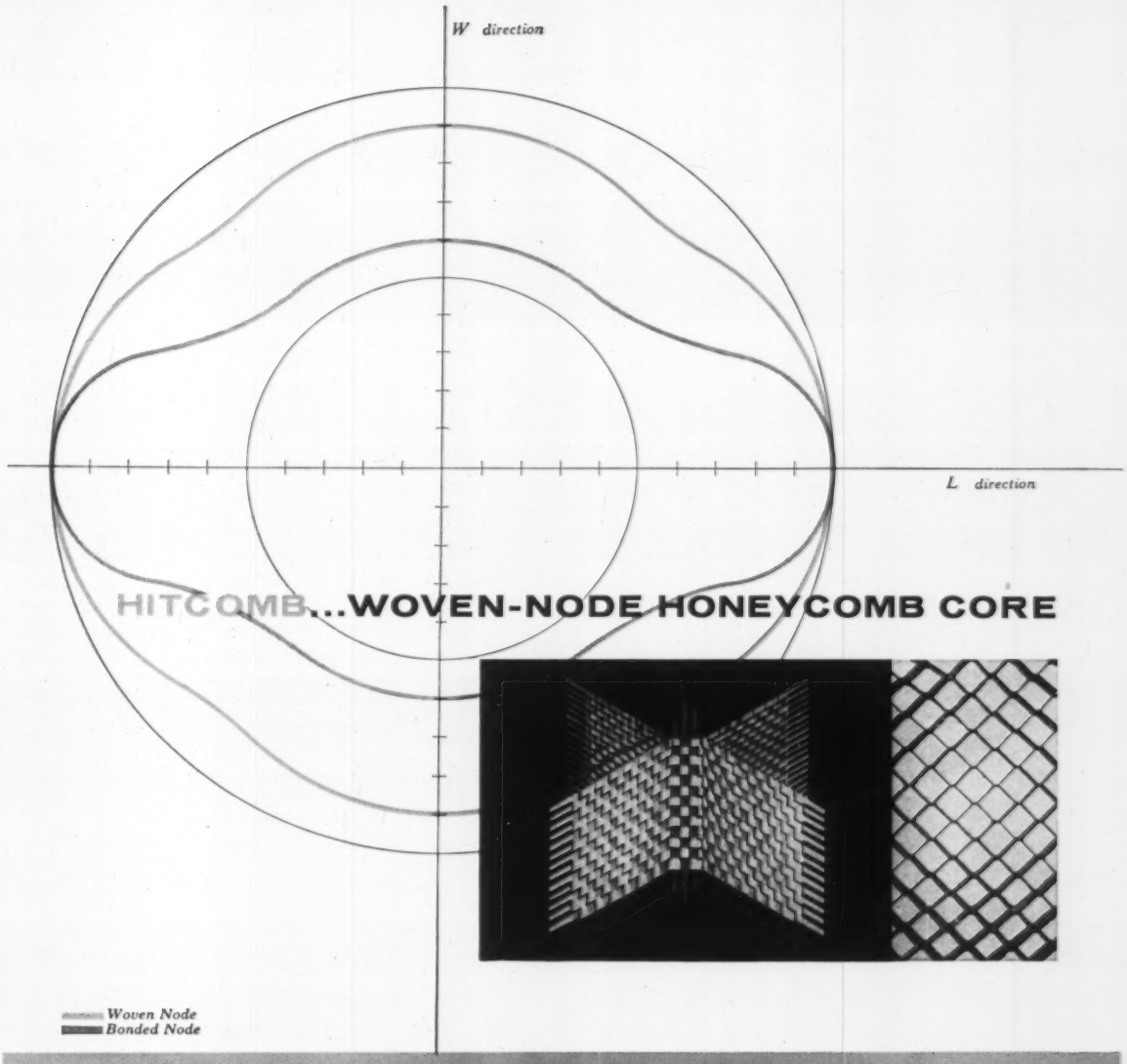

HITCOMB...WOVEN-NODE HONEYCOMB CORE

Woven Node
Bonded Node

a new high in high temperature structural core material

HITCOMB is a new concept in core for high-temperature sandwich panel applications. HITCOMB, made by a unique three-dimensional weaving process, demonstrates isotropic physical properties at elevated temperatures, since it has square cells and does not depend on an adhesive bonded node line.

This material is already showing superiority through structural applications in space craft capsules, as well as in structural heat shields. HITCOMB fiber glass core exceeds all physical property requirements of specification MIL-C-8073A. It is available in fiber glass and REFRASIL® for use where ultra-high temperatures may be encountered. Both REFRASIL and fiber glass forms are currently available with many of the popular resin systems such as phenolics, phenyl-silane, silicones, polyesters and epoxies.

Write for Technical Products Bulletin PD6-2

H. I. THOMPSON FIBER GLASS CO. 1733 Cordova Street • Los Angeles 7, Calif. • REpublic 3-8181

WRITE OR CALL YOUR NEAREST HITCO FIELD ENGINEER: EASTERN: Tom Kimberly, 38 Crescent Circle, Cheshire, Conn., BR. 2-6544; Fred W. Muhlenfeld, 6659 Loch Hill Rd., Baltimore 12, Md., VA. 5-3135 • **MIDWEST:** Burnie Weddle, 3219 W. 29th St., Indianapolis 22, Ind., WA. 5-8685 • **SOUTHWEST:** Marshall Morris, 2850A W. Berry, Rm. 7, Fort Worth, Tex., WA. 4-5629 • **NORTHWEST:** J. L. Larsen, 5757 Oaklawn Pl., Seattle, Wash., PA. 5-9311 • **SAN DIEGO:** John Vail, 9048 Haverour Way, JU. 3-6393 • **CANADIAN PLANT:** THE H. I. THOMPSON CO. of CANADA LTD., 60 Johnston St., Guelph, Ont., TA. 2-6630

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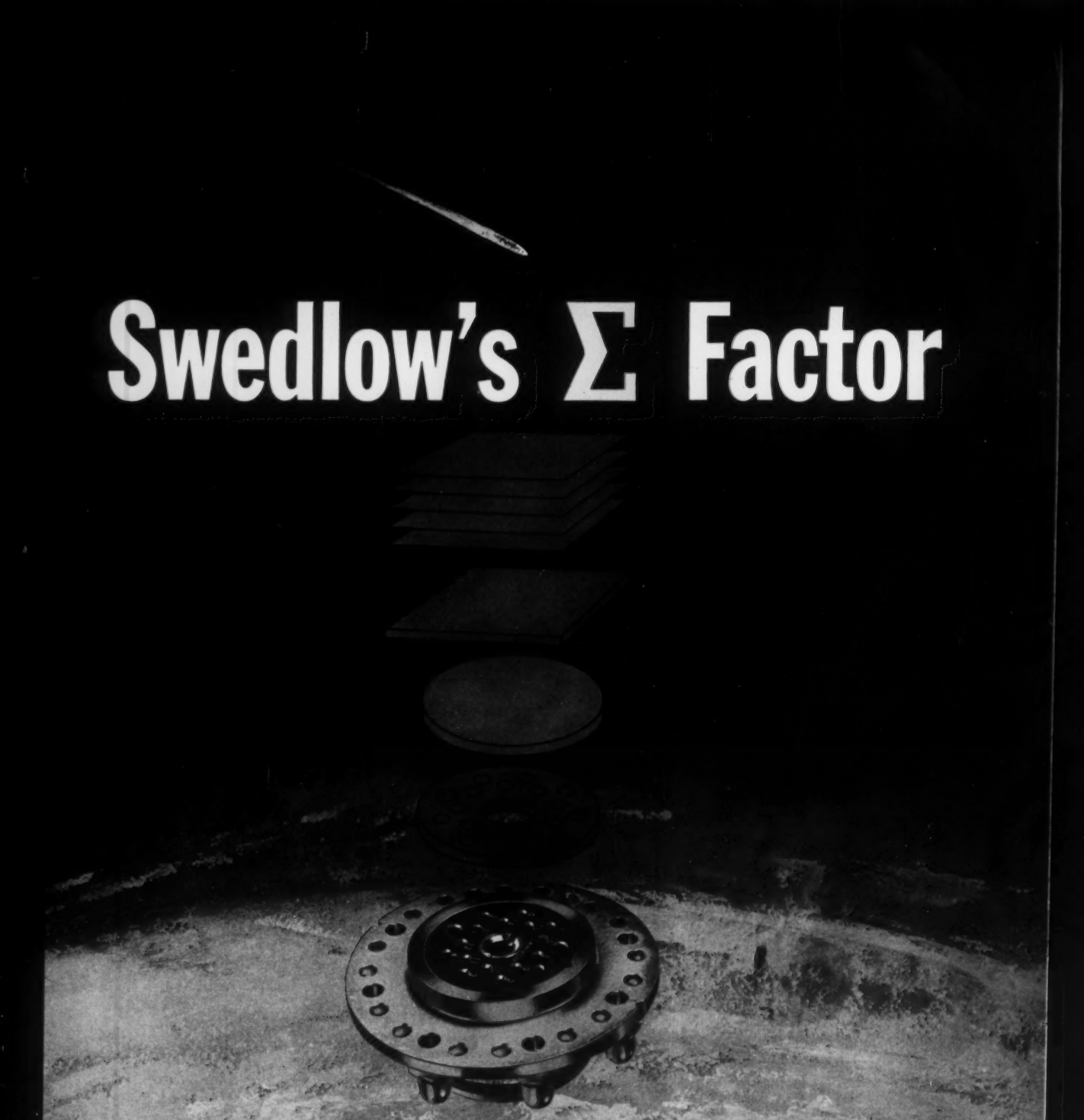
Swedlow's Σ Factor



In Swedlow's high temperature laminates — vital to "Cannon Plugs"

"Sigma": the "sum" of the skill and insight needed to solve challenging problems in reinforced plastics. Swedlow phenolic insulative laminates must combine diverse properties for many of Cannon Electric Company's reliable high temperature connectors—now found on most missiles.

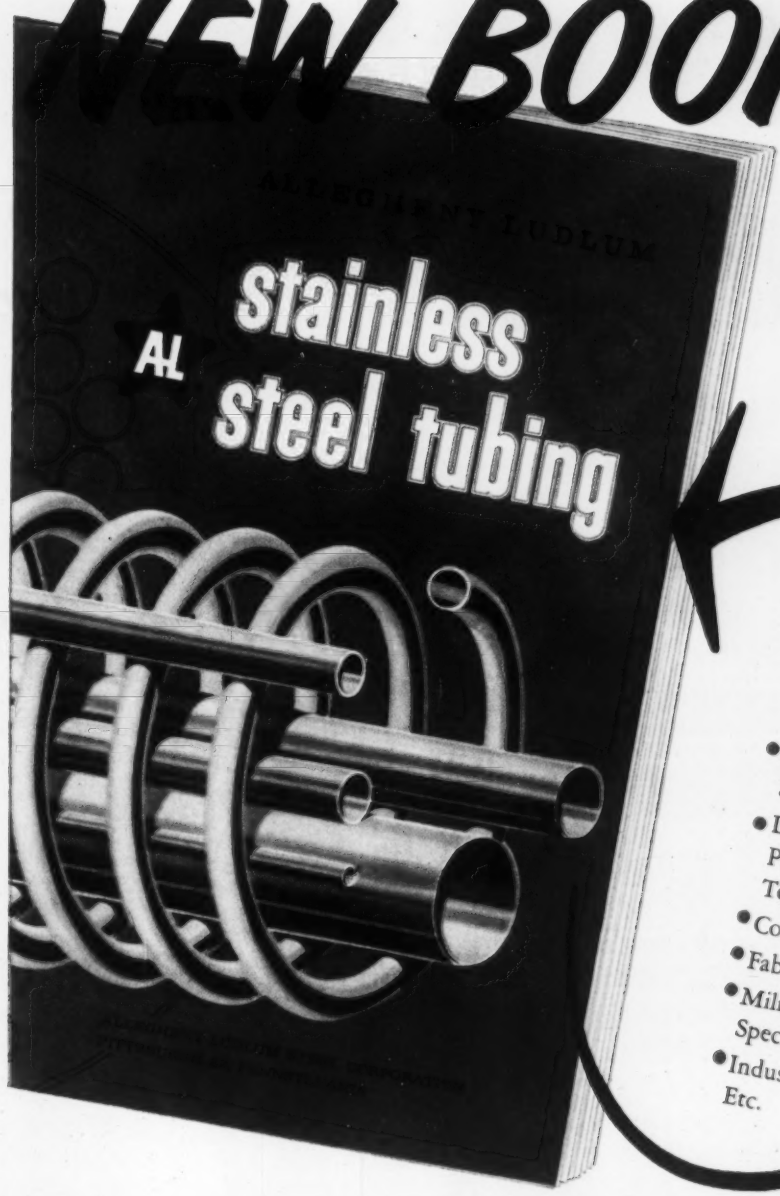
The insulation must maintain mechanical integrity. It must prevent heat passage to critical components, a tough job during launching and reentry. The laminates must therefore combine good electrical properties with mechanical strength, resistance to high temperatures and thermal shock, low water absorption, and good machinability. They are produced by Swedlow in thicknesses to meet industry requirements, in sheets up to 48" x 96" or in finished parts. Additional Swedlow high temperature materials include epoxy, silicone, asbestos-phenolic, composite graphite, and many other advanced materials for the future.

Apply some of this Swedlow Σ to your next difficult materials problem. Send for Technical Bulletin "S"—"High temperature phenolic laminates," to Dept. 18.

SWEDLOW Inc. / LOS ANGELES 22, CALIFORNIA / YOUNGSTOWN 9, OHIO

Swedlow

NEW BOOKLET on STAINLESS STEEL TUBING sent on request



PARTIAL LIST OF CONTENTS

- Stainless Steel grades
- Product data on Seamless Tubing and Welded Tubing
- Size range Stainless Pipe & Tubing
- Design data—Internal Pressures—Elevated Temperatures, etc.
- Corrosion resistance
- Fabrication data
- Military & Aircraft Specifications
- Industry's uses

Etc.

This 36-page booklet newly published by Allegheny Ludlum is packed with technical data and authoritative information on both welded and seamless stainless steel tubing. There are more than 20 tables for ready reference and many photographs.

It will be helpful to design engineers and others interested in solving the many critical and demanding pipe and tubing applications.

The booklet contains the best and latest information available on product and design data on the subject—the partial contents listed give some idea of its scope. You'll want a copy for your files.

Write for your free copy of Allegheny Stainless Steel Tubing, ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pennsylvania. Address Dept. MM-8.***

1287

ALLEGHENY LUDLUM

Export distribution: AIRCO INTERNATIONAL

EVERY FORM OF STAINLESS . . . EVERY HELP IN USING IT

AL

For more information, circle No. 435

For more information, turn to Reader Service card, circle No. 436

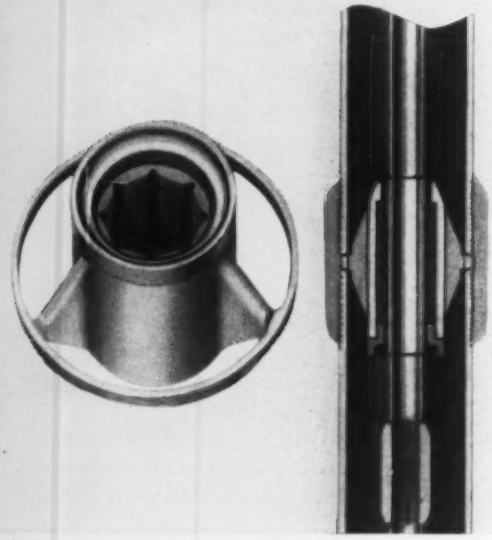
NEWS FROM GOODRICH-GULF

RUBBER BEARINGS KEEP PUMP SHAFT RUNNING SMOOTH

Ameripol Rubber is used for the special Cutless Bearings which support deep-well shafts on several types of pumps for use in wells, tanks, sumps or reservoirs, made by The Deming Company of Salem, Ohio. The bearings are available from Lucian Q. Moffitt, Inc., Engineers and National Distributors, 333 South Main Street, Akron, Ohio.

The Ameripol polymer used is tough, and is not affected by sludges in waste chemicals often found in water. The Cutless Bearing is fluted, thus sand or grit present in the fluid being pumped is quickly washed away. With conventional metal bearings, abrasive solids cut and score the bearing, leading to a loose fit and vibration.

This type of water-lubricated rubber bearing is particularly applicable on industrial equipment where bearings are submerged, as well as propeller shafts of boats.



NEW MARKET FOR RUBBER IN THE COMPACTS

The automotive industry's success in "selling small" has meant a big new market for Styrene-Butadiene Rubber. This compact car, for example, carries approximately 48 pounds of SBR parts.

Largest uses by weight are the tires. Other SBR applications include battery, steering linkage and covers, clutch and brake pedals, engine mounts, and a wide assortment of grommets, bushings, and seals throughout the vehicle.

While many parts are SBR, the requirements naturally vary, and many different polymers are used. As the world's largest source of synthetic rubber, with the broadest range of polymers, Goodrich-Gulf is in unique position to help rubber product fabricators supply this new market.

Ameripol
THE PREFERRED RUBBER

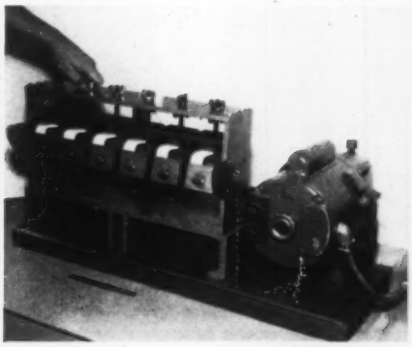
RUBBER GETS A "COMPLETE PHYSICAL CHECKUP" AT GOODRICH-GULF SALES SERVICE LABORATORY

These scenes are representative of dozens of special tests conducted at the G-G Sales Service Laboratory for the benefit of our customers. Here polymers are checked in different compounds to measure the properties needed in individual applications. Problems are thoroughly analyzed so that sound technical recommendations can be made. Evaluations and special tests on polymers you use are available to you through Goodrich-Gulf Technical Service.
Address: 1717 East Ninth Street, Cleveland 14, Ohio.

Sandpaper rubs rubber raw to check resistance to abrasion.

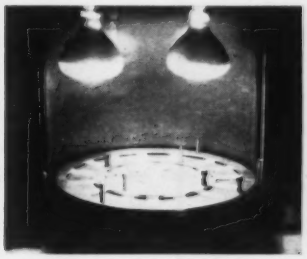
Ease of flow and processing determined by Mooney viscosity test.

Rebound of the swinging hammer gives measure of resilience.



Specimens are flexed hour after hour until failure.

Test strips torn apart to measure strength and elongation.



Effects of sunlight on color evaluated by ultraviolet tests.

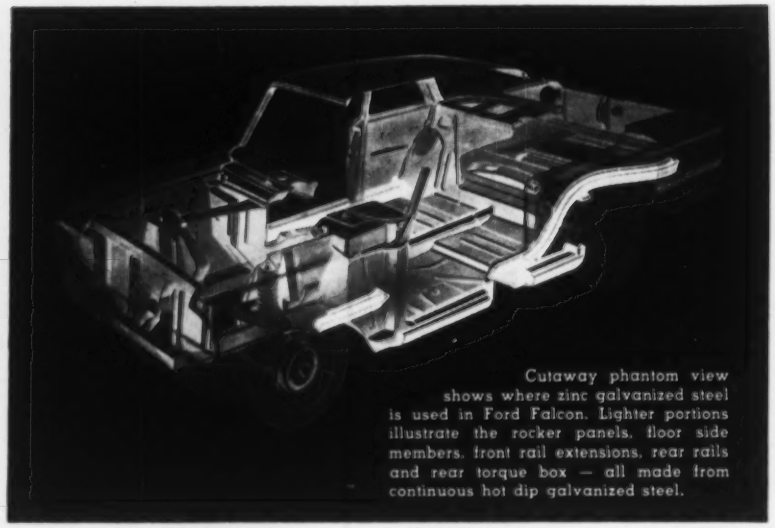
Goodrich-Gulf Chemicals, Inc.

THE ONE TO WATCH FOR NEW DEVELOPMENTS

For more information, turn to Reader Service card, circle No. 405

ZINC GALVANIZING

Protects Vital Body Parts In FORD MOTOR CO.'s Compact Cars



Cutaway phantom view shows where zinc galvanized steel is used in Ford Falcon. Lighter portions illustrate the rocker panels, floor side members, front rail extensions, rear rails and rear torque box — all made from continuous hot dip galvanized steel.

COMPARATIVE TESTS PROVE GALVANIZED STEEL BEST CORROSION GUARD FOR VULNERABLE PARTS IN UNITIZED CONSTRUCTION

After 2½ years of evaluation tests, FORD MOTOR COMPANY'S Advanced Body Development decided galvanized steel was the best material for protecting unitized bodies against corrosion.

The box type construction of unitized bodies makes corrosion a critical problem because moisture and road salts become trapped in vital underbody parts. Zinc galvanized steel is expected to give these parts 2½ to 3 times longer life than conventional low carbon steel. This would mean that they will be corrosion-free for 10 to 12 years under normal use.

This is the reason why Ford and other auto makers are now using galvanized steel for the basic framing members of the new unitized bodies.

ANOTHER EXAMPLE OF THE VERSATILITY OF CONTINUOUS GALVANIZED STEEL

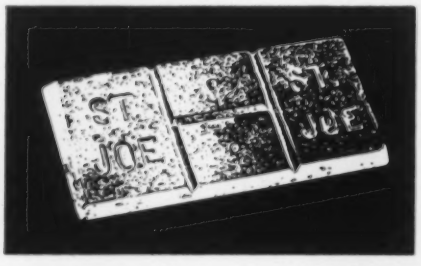
The use shown here is one of a wide variety of applications where continuous galvanized sheet provides the successful combination of protection plus formability. This pre-protected metal can withstand torturous deformation without losing its corrosion-resistance. The zinc coat flows with the base metal — does not chip, flake, powder or peel under severe forming operations.

St. Joseph Lead Co. supplies zinc "electronically matched" to virtually any specifications which operators of continuous galvanizing lines may require.

ST. JOSEPH LEAD CO.

ST. JOE

250 Park Avenue, New York 17, N. Y.

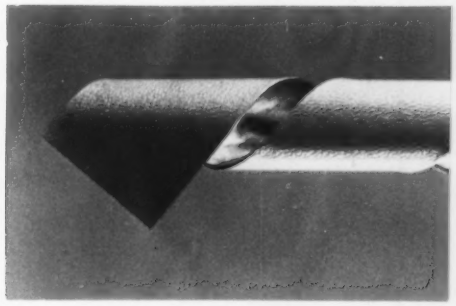


ZN-166

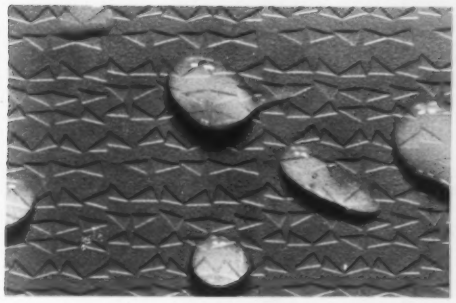
For more information, turn to Reader Service card, circle No. 408

For more information, circle No. 424 ➤

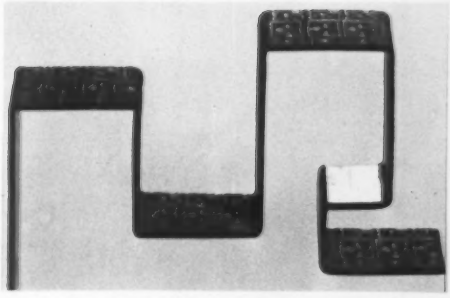
Twist it



Wet it



Form it

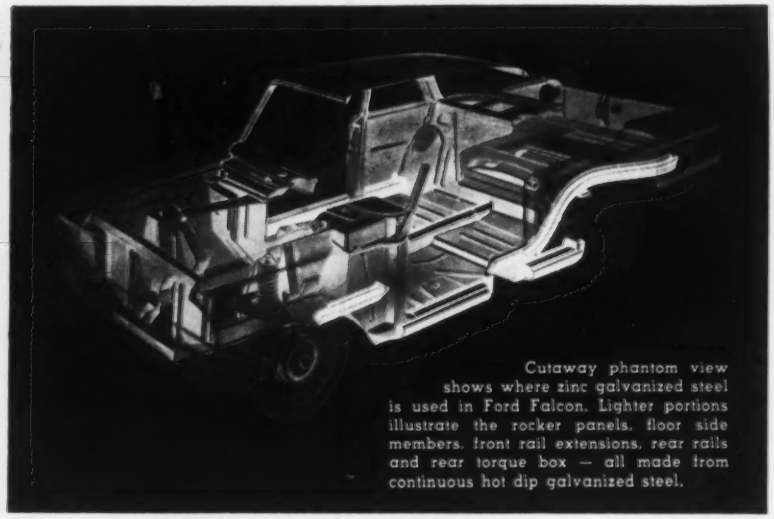


Design with it

USS Vinyl Coated Steel Sheet ● Here is the look and feel of leather or fine cloth, or any other texture you want, bonded and cured directly and permanently to steel. Here is a complete spectrum of color, too, in a material that is inexpensive, versatile, tough enough to take the hard knocks and strong enough to be used in the most demanding applications. USS Vinyl Coated Steel Sheet is easy to clean, resists sporting and stain

ZINC GALVANIZING

Protects Vital Body Parts In FORD MOTOR CO.'s Compact Cars



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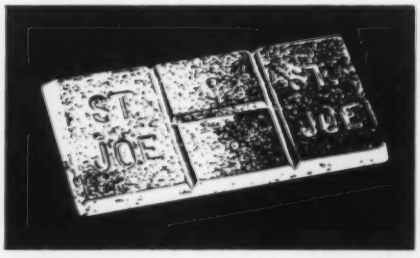

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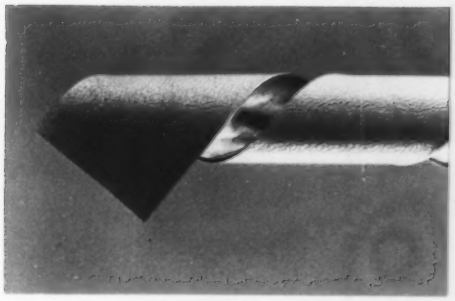
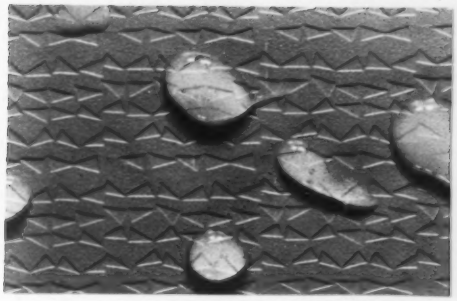


Wet it



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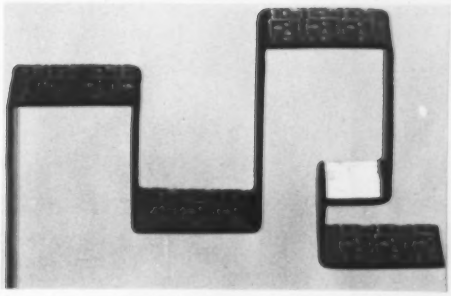
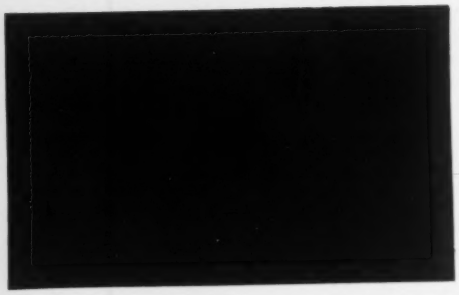
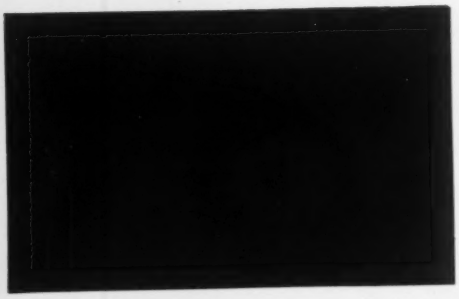
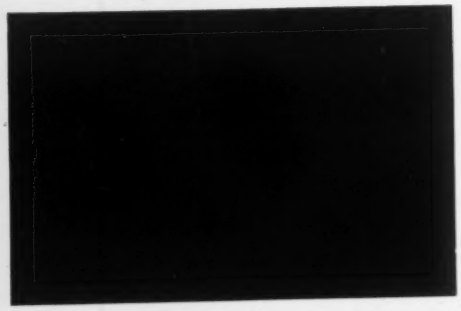


Design with it







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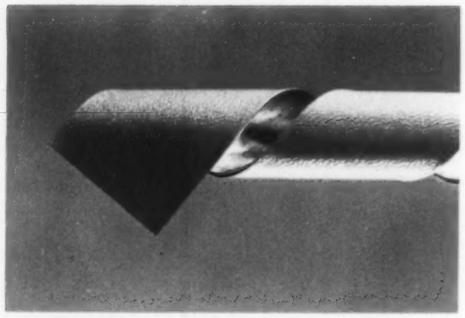
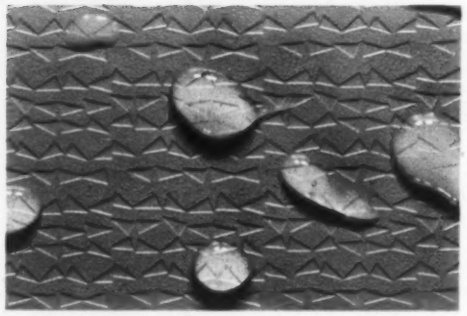
Twist it The surface won't crack or peel. Here is tough vinyl that can be produced in any texture, any color, with the strength of steel.



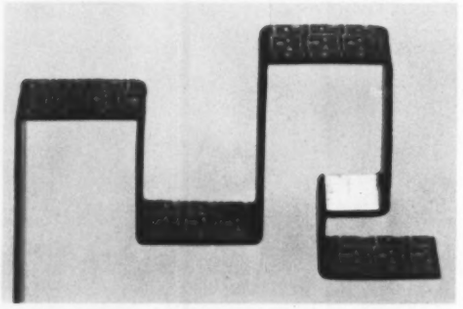
Four examples of the many patterns

Wet it Try to spot it. USS Vinyl Coated Steel Sheet won't water spot. You can't stain it with die lubricants, alkaline cleaners, fountain pen ink, alcoholic beverages, detergents, acid cleaners, nail polish, or fruit acids.



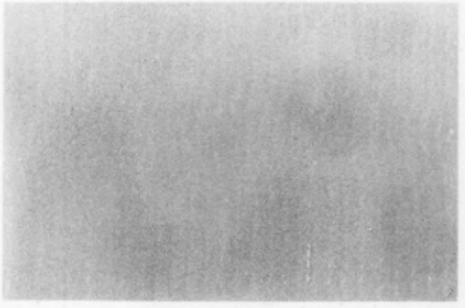
which can be ordered

Form it You can slit it, punch it, draw or roll form it. USS Vinyl Coated Sheets can be lock seamed easily. Special processes have been developed so you can weld it with no damage or discoloration to the finish.



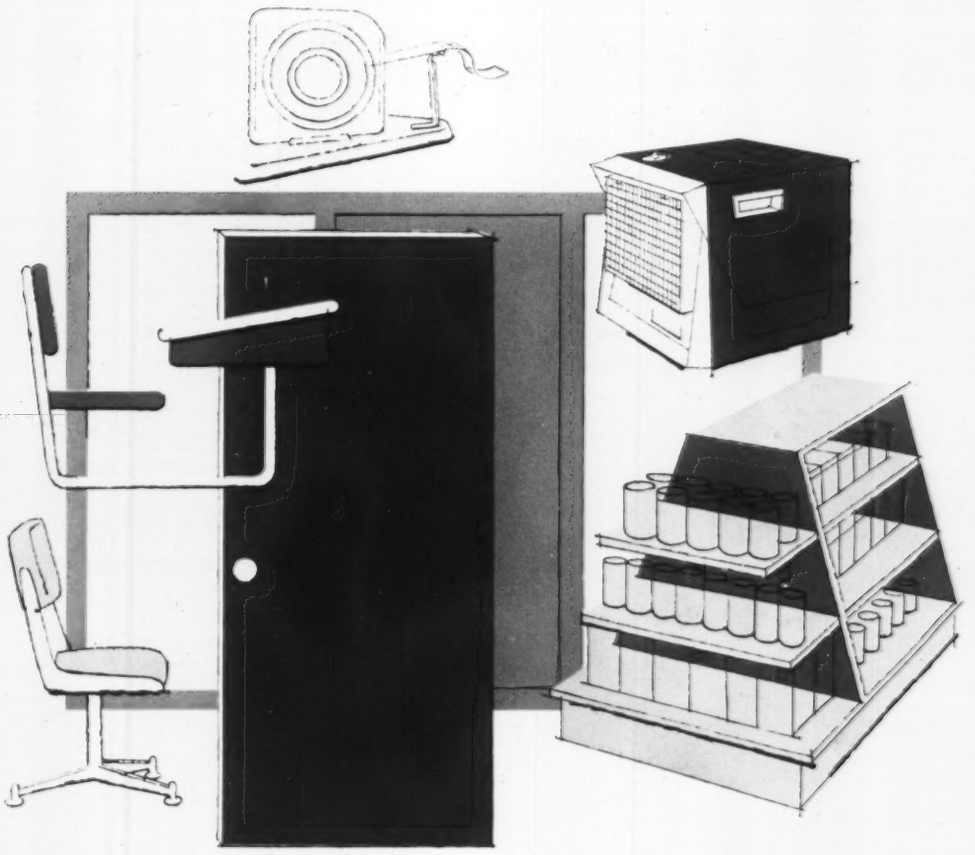
in vinyl coated steel.

Design with it Building interiors, doors, appliances, furniture, automobile and station wagon interiors, railroad car interiors, business machines, store shelving, switch panels, almost any product that is subjected to abuse.



USS TRADEMARK **Vinyl Coated Steel**

This mark tells you a product is made of modern, dependable Steel.



Here are just a few suggested applications for USS Vinyl Coated Sheets: A colorful room divider or partition. Face panels are interchangeable; panels of different colors or textures can be easily inserted. A portable space heater that is scuffproof, also available in any color or texture. A lobby door that defies scuffs and hand prints, is easily cleaned; color and texture can adapt to any interior decoration. For long term service, smart appearance with practically no maintenance, vinyl steel store shelving meets the requirements of heavy use in any color. Contemporary office chairs covered with USS Vinyl Coated Sheet that will last.They look and feel like leather; actually they're strong steel. A school desk that will take years of hard knocks, yet look like it's going through its first term. For the home, a tape dispenser with extra sales appeal because it has the look and feel of fine leather.

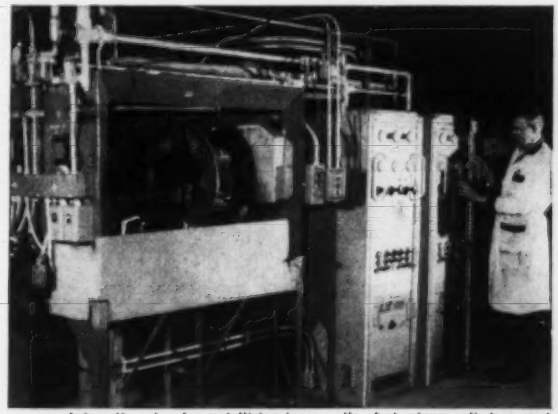
USS Vinyl Coated Sheets can be adapted to these and thousands of other uses. It is competitive in price with other materials. It will not support combustion and it has a dielectric strength of 750 volts per mil of coating thickness. It is available in gages from 16 through 32, widths from 24 to 52 inches, in coils up to 10,000 lb. Vinyl coatings are 0.008 to 0.020 in. thick.

Samples and technical assistance are readily available from U. S. Steel. Or send for our 20-page, full color technical book, "USS Vinyl Steel." Write United States Steel Corporation, Room 6124, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS TRADEMARK **United States Steel**

Flame sprayed metal increases wear resistance better than 10 times

AIDS WEIGHT REDUCTION



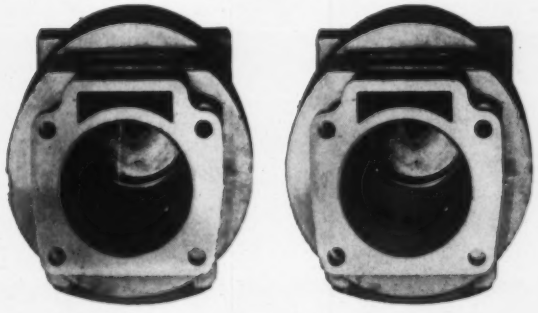
Automatic setup for metallizing inner walls of aluminum cylinders used in lightweight gasoline engines. Cabinet in foreground houses six-station rotary setup; automatic control panels are at right.

Many methods, including cast-iron cylinder liners and chrome plating, have been tested for wear resistance in lightweight gasoline engine blocks of aluminum.

Best of these methods experienced breakdowns in less than 400 hours. Now they are metallized with METCO Sprabond (molybdenum alloy) as a bonding agent, followed by a coating of sprayed steel alloy.

Test runs of over 4,000 hours show little or no wear of the metallized surface. Finish thickness is .007"; weight – a few grams. Cast-iron liners weighed almost ½ pound.

Cylinder at left machined ready for flame spraying; one at right has been metallized and hone finished.



Closeup of automatic six-station rotary setup. Cylinders are individually rotated at 150 rpm. Cylinder is loaded on table at Station 1, moved through Stations 2 and 3 for pre-heating by torch. At Station 4, bonding coat is applied by the gun nozzle which feeds into the rotating cylinder. Low alloy steel is applied at Station 5 and cylinder cools at Station 6. Cylinder walls are finished by honing.

New engineering data bulletin

Bulletin 136B—The METCO Flame Spraying Processes, provides basic engineering and application data on flame sprayed coatings of metals, ceramics, carbides and other high melting point materials. 16 pages. Send coupon for free copy.

Metallizing Engineering Co., Inc.

METCO

Flame Spray Equipment and Supplies
1175 Prospect Ave., Westbury, L. I., N. Y.
Telephone: Edgewood 4-1300 Cable: METCO
In Great Britain: METALLIZING EQUIPMENT CO., Ltd.
® Chobham-near-Woking, England

Don Watson
Please send Bulletin 136B.

name title

company

address

city zone state

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DOW

NEWS ABOUT PRODUCT DESIGN AND MATERIALS

Win the housewife's approval . . . and products designed for the home score success in the marketplace. By helping designers create colorful, durable products that are effortless to care for, easy to use . . . modern plastics assist in gaining the all-important nod of approval from the lady of the house. In these new products, for example . . .

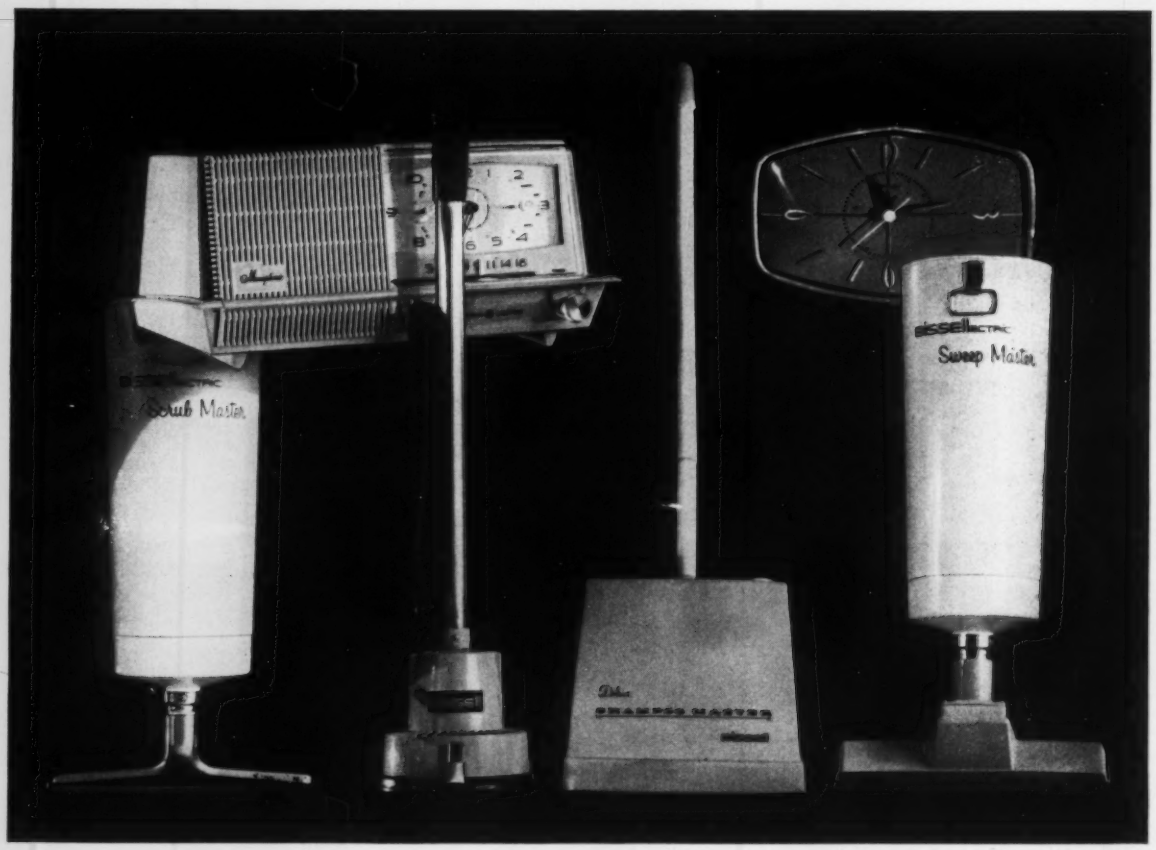
TODAY'S PLASTICS STAR IN NEW HOUSEWARE DESIGNS

Whether the design is a new product or improvements for an old standard, Dow plastics are ready to help the designer. They provide a vast array of thermoplastics formulations—each with particular specialties. Take Styron®, for example . . .

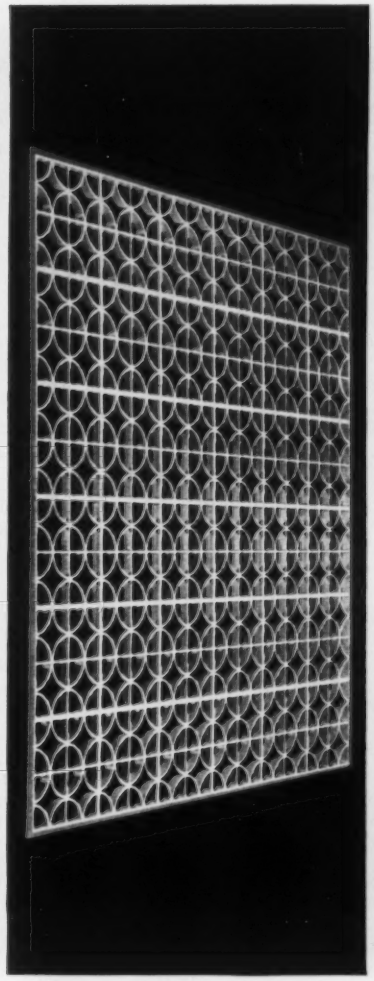
The workhorse of modern plastics, Styron (Dow polystyrene) permits the designer complete color choice, with attractive surface finish assured. This material affords good flexural strength—provides excellent dielectric properties and low water absorption. Best of all, Styron is low in cost—molds, extrudes and thermo-forms easily—and is offered in 20 different formulations that spotlight particular design characteristics.

For example, in the new combination appliance designed both to vacuum rugs and scrub floors (illustrated below), tanks are made of Styron 475, developed specifically for high impact strength—three to five times greater than general purpose polystyrene materials. This formulation also provides the tank housing for the hard-working rug shampoo device.

Styron 369, a formulation that combines excellent heat resistance and good impact strength, makes a colorful case for the high-styled clock radio. And the wall clock takes advantage of other versatile features of Styron—the case is opaque while the protective dial cover is crystal clear.



For outdoor relaxation, handsome chairs are laced with cord of PVC, Dow polyvinyl chloride. Excellent aging characteristics, quick recovery from loads combine to assure durability and long-lasting comfort. In a wide range of colors, PVC materials clean easily.



For privacy on the patio, new wall divider grilles offer novel designs, maintain their good looks for years. Molded of Zerlon®, they are exceptionally strong, resist outdoor weathering . . . and stand up under blazing sun or freezing cold.

Cans open in a hurry with electricity turning the crank. And this can opener is a breeze to keep clean because the stand and housing are of Tyril®. Remarkably stain-resistant, this material withstands foods, oils, waxes, soaps . . . even solvents and many chemicals.

LOOKING FOR NEW MATERIALS?

The Dow family of thermoplastics provides one of the widest lines of materials and formulations available in the industry today. More than likely, there are Dow plastics that can help you today in designing products for tomorrow. We'll be glad to help with specialized technical service—from helping select the right formulation to assisting in color styling, as you wish. Just write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Merchandising Department 1721CD8.

THE DOW CHEMICAL COMPANY

Midland, Michigan

DOW

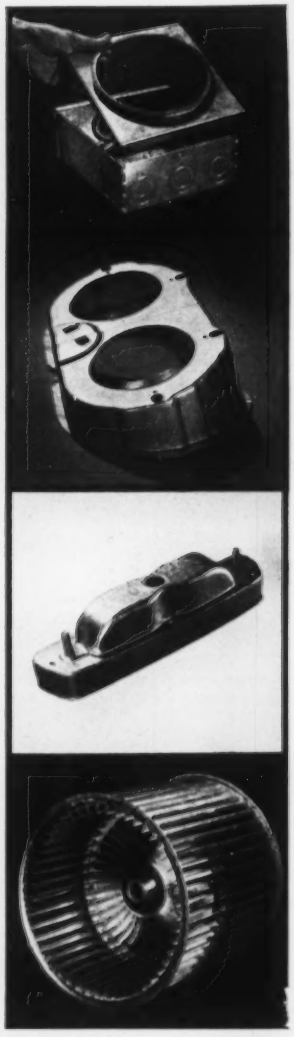
For more information, turn to Reader Service card, circle No. 442

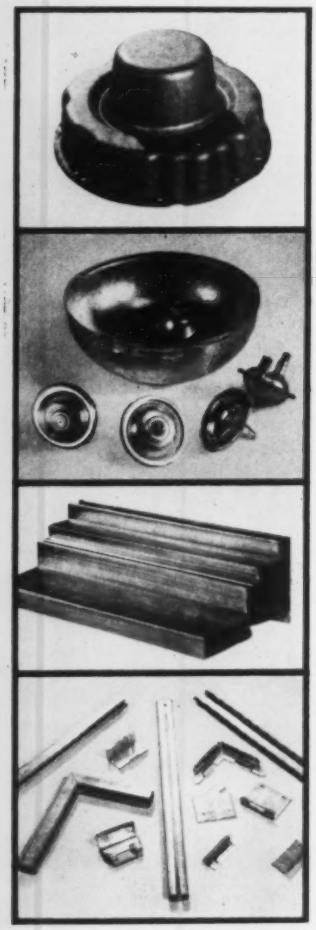
ARMCO STEELS / for better products • lower costs

Galvanized Steel

Armco ZINCGRIP Steel Protects Against Rust and Corrosion at Minimum Cost

Special hot-dip zinc coating that doesn't flake or peel gives formed steel parts economical durability.

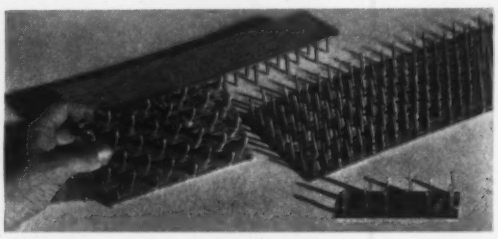




If you are making parts like these—parts that require the strength of steel yet must have low cost protection against rust—Armco ZINCGRIP Steel offers you opportunities to save money and improve product performance. Here's why:

* **ZINCGRIP STEEL has the lasting protection of a full-weight hot-dip zinc coating (1.25 oz. or heavier).**
* **The special coating on ZINCGRIP won't flake or peel despite forming, drawing, piercing, or other severe working.**
* **Armco's patented continuous process produces a zinc coating of uniform thickness and composition.**
* **For only a few cents' premium over cold-rolled steel, you eliminate the need for plating, painting or other protection.**
* **The economy and durability of ZINCGRIP STEEL has been service-proved in thousands of applications for more than 25 years.**

Let us send you complete information on Armco ZINCGRIP Steel so you can determine how its advantages can be most effectively used in *your* products. Armco Steel Corporation, 2370 Curtis Street, Middletown, Ohio.



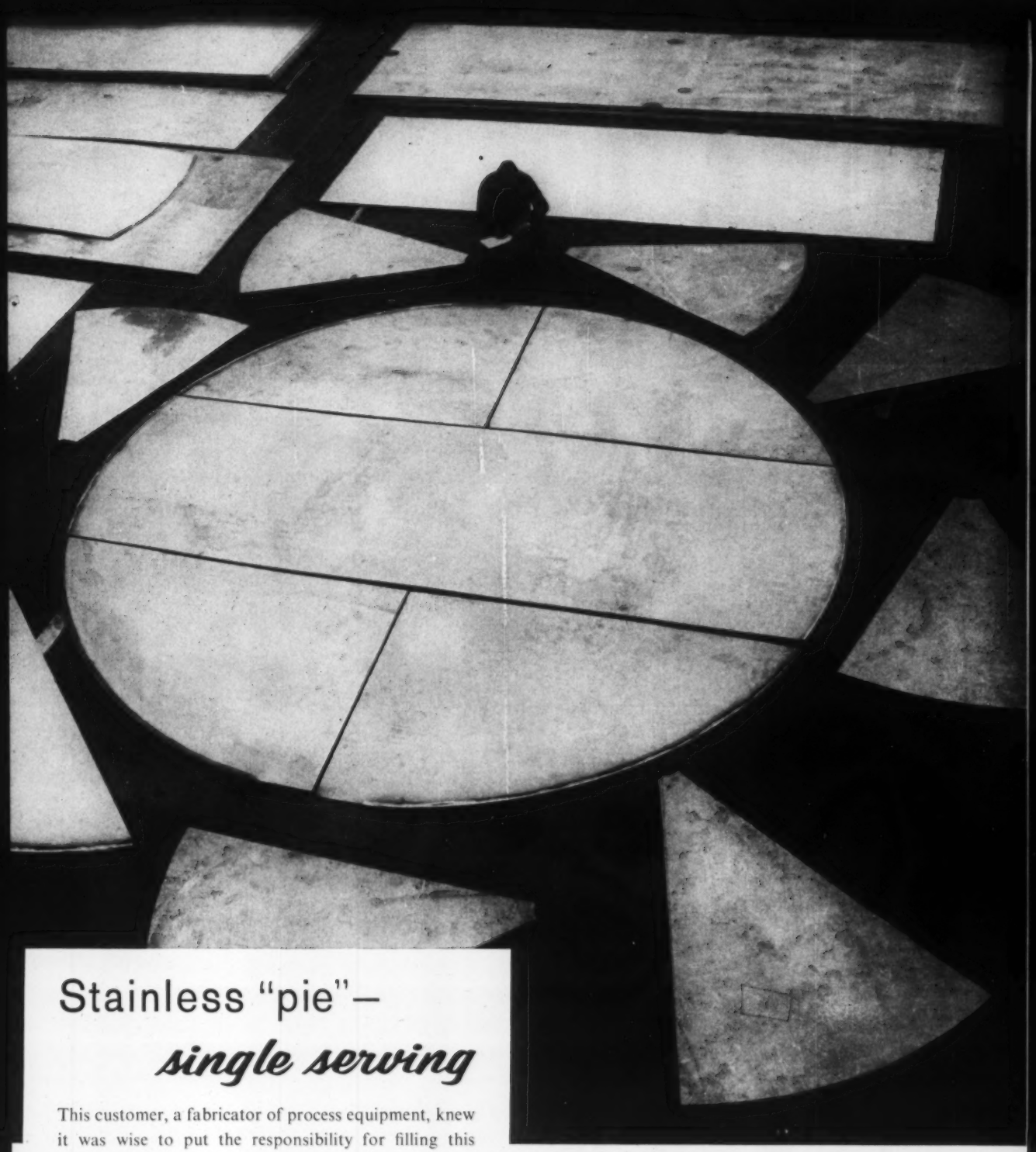
New steels are born at Armco

ARMCO STEEL

ARMCO

Armco Division • Sheffield Division • The National Supply Company • Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Union Wire Rope Corporation

For more information, turn to Reader Service card, circle No. 353



Stainless "pie"—
single serving

This customer, a fabricator of process equipment, knew it was wise to put the responsibility for filling this stainless steel order in the hands of a single producer—G. O. Carlson, Inc. He knew that our specialists, working with modern equipment, would make each item of the order "to specification." And he also knew that our delivery promise is a trust that we fulfill.

For your order—or orders—of stainless steel plate and plate products, come to Carlson. Here skilled men, working with the finest equipment, are determined to match your every wish.

G.O.CARLSON *Inc.*

Producers of Stainless Steel

126 Marshallton Road
THORNDALE, PENNSYLVANIA
District Sales Offices in Principal Cities

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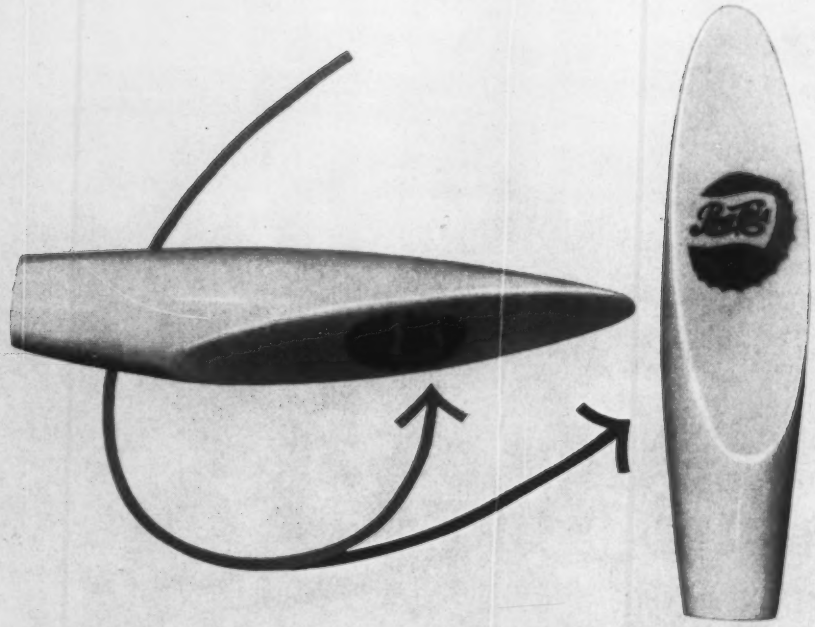

Another way to make folks say, "Make mine a Pepsi"

Photographs can't do justice to the beauty, utility and durability of this Pepsi-Cola dispenser handle. Molded of gleaming white melamine with the famous red, white and blue Pepsi bottle cap in permanent molded-in color, it provides that all-important instant identification to the thirsty millions who prefer this popular beverage. Handsome, yes, plus all the strength and rigidity needed to meet the rigorous demands of fountain service.

The Pepsi handle is not an ordinary molding job. In fact, it involves some rather unusual techniques which come only with years of experience. And that is, of course, a mighty good reason to specify CMPC on your next job.

This is another CMPC "White Gloves" molding. For maximum protection against material contamination, this product was molded under highly controlled production conditions involving special dust control measures and a protective materials handling system. This is another example of CMPC's specialized techniques and facilities for producing the best in molded plastics.

CMPC

CHICAGO MOLDED PRODUCTS CORPORATION
1020 F North Kolmar Avenue
Chicago 51, Illinois

For more information, turn to Reader Service card, circle No. 394

A new family of materials to meet special problems

•

SHOCK
STRESS
ABRASION

AMSCO® ALLOYS

In addition to austenitic manganese steel castings—long known for their exceptional service life in mining, construction, quarrying and milling applications—Amsco now offers *seven* other ferrous alloy materials. These include specially alloyed manganese steels, chrome moly steels, high strength alloyed steels and alloyed cast irons.

Each has particular advantages for specific service requirements, involving various combinations of impact, stress and wear. Check the brief facts on these alloys below. Then call in an Amsco sales engineer to assist in selecting the *one best* material to meet your application needs.

AMSCO ALLOY DESIGNATION	DESCRIPTION AND USES	MECHANICAL PROPERTIES
MY	Heat-treated, chromium alloyed manganese steel... for use in light-to-medium weight castings requiring modest improvement in growth and distortion, and increased stiffness.	tensile strength ..... 120,000 psi yield strength ..... 56,000 psi elongation ..... 45% reduction of area 30%
MML	Heat-treated, molybdenum alloyed manganese steel... for castings requiring improved weldability, for extremely heavy metal sections, and castings exposed to excessive heating environments.	tensile strength ..... 120,000 psi yield strength ..... 52,000 psi elongation ..... 50% reduction of area 40%
MMH	Heat-treated, molybdenum alloyed manganese steel... for use in castings requiring optimum mechanical properties and wear resistance. Provides improved stiffness and resistance to peening and flow.	tensile strength ..... 120,000 psi yield strength ..... 65,000 psi elongation ..... 20% reduction of area 18%
CML	Heat-treated, air-hardening chrome-moly steel... for casting applications involving scouring or grinding wear. Suitable for more complex casting designs.	tensile strength ..... 155,000 psi yield strength ..... 130,000 psi elongation ..... 10% reduction of area ..... 15% hardness ..... 275-375 BHN
CMH	Heat-treated, air-hardening chrome-moly steel... exhibits potentially improved wear resistance over CML (above), when shock loading is not sufficiently severe to cause breakage.	tensile strength ..... 155,000 psi yield strength ..... 130,000 psi elongation ..... 6% reduction of area ..... 7% hardness ..... 300-400 BHN
CS	Martensitic, multiple alloy steel with chromium, nickel and molybdenum... combines high mechanical strength with good abrasion and wear resistance.	tensile strength ..... 220,000 psi yield strength ..... 195,000 psi elongation ..... 8% reduction of area ..... 20% hardness ..... 300-500 BHN
HC	High chromium cast iron... provides outstanding abrasive wear resistance, where impact force is low but particle velocity and scouring forces are high.	tensile strength ..... 60,000 psi transverse strength ..... 7,000 lbs. deflection ..... 0.12 in. hardness ..... 400-600 BHN

For further information
—write for technical bulletin on "Amsco Ferrous Alloy Castings".

AMERICAN Brake Shoe COMPANY

AMSCO

American Manganese Steel Division • Chicago Heights, Illinois

For more information, turn to Reader Service card, circle No. 378

In steak or plating, thickness counts. A good thick layer of Nickel under the chrome will give your product a finish that not only *looks* like quality but also *keeps* that look despite hard use.

Brushed Nickel-Chrome...an enduring finish that gives a quality look at a practical cost

Look at the door of this built-in oven ... at the top of the drop-in range.

The rich beauty you see is brushed Nickel-Chrome Plating.

You may have heard of this finish as "brushed chrome" or "satin chrome." By any of these names, brushed Nickel-Chrome Plating offers you a way to dress up your products at little – if any – increase in production cost!
Here are five big reasons why:

Quality Appearance. A brushed Nickel-Chrome finish tells your customer that the article he is buying is of high quality – inside as well as on the surface.

Durability. This finish keeps on saying "quality" despite hard use. One or even two punishment-taking layers of Nickel, flash-coated with chrome, resist nicking, scratching, wearing, and corrosion. What's more, this finish resists staining, is easy to clean.

Easy to Fabricate. Brushed Nickel-Chrome can be ... is being applied to all the easy-to-fabricate metals – steel, zinc, aluminum, copper, brass – to take advantage of the physical and mechanical properties of these metals. Less common metals can also be readily plated.

Versatility. Brushed Nickel-Chrome has many unique advantages. For example, by selective buffing, you can get bright trim effects without using trim hardware.

Practical Cost. Experience of manufacturers already using brushed Nickel-Chrome shows that this eye-catching finish costs only a few pennies more than ordinary finishes.

With Nickel in ample supply as far into the future as any man can see, you can take advantage of brushed Nickel-Chrome Plating to give your products extra sales appeal. For more ideas, write for our booklet, "Practical Answers to 40 Practical Questions about Nickel Plating."

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

INCO Inco Nickel... *makes plating perform better longer*

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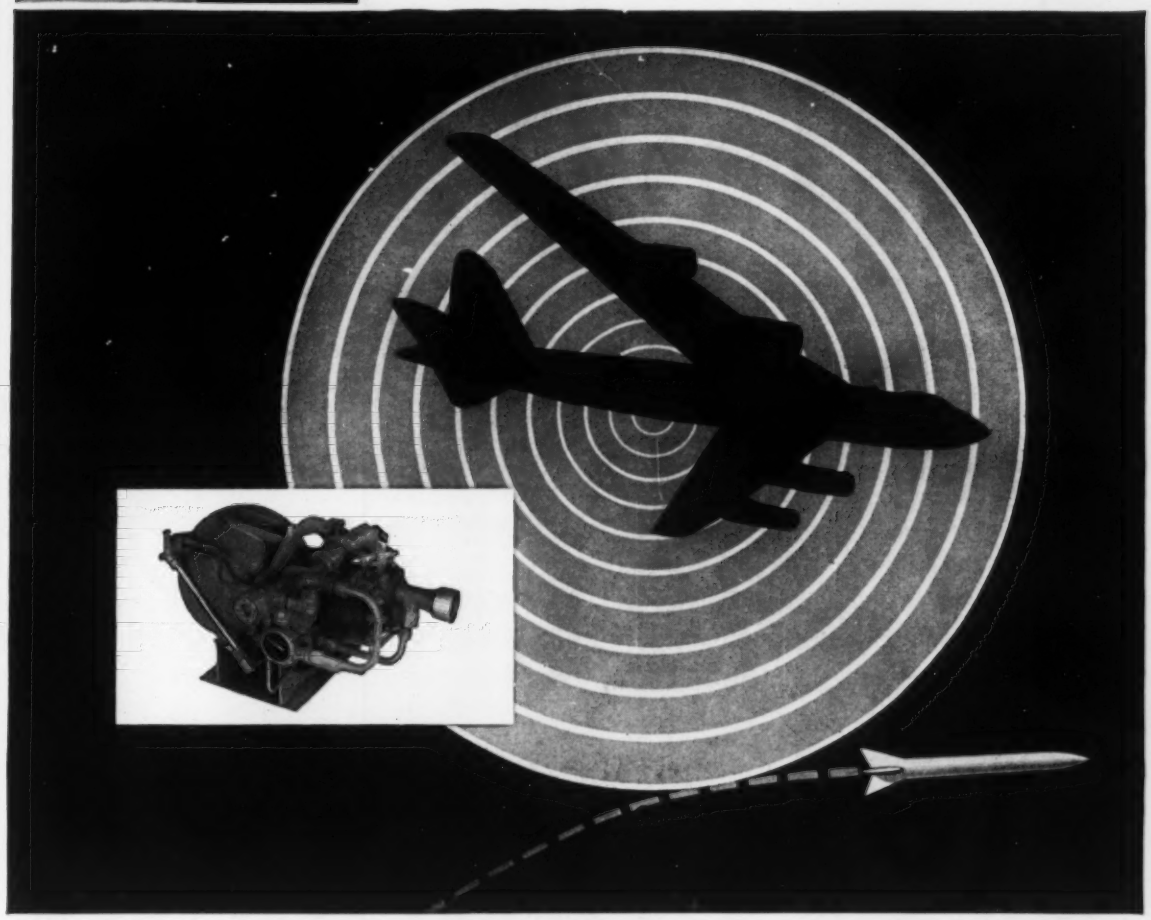
3M COMPANY CHEMICALS

THE RAW MATERIALS OF PROGRESS



HOW TO HOLD A JAM SESSION 8 MILES UP

Vickers active cooling system (inset) uses FC-75 in countermeasures system

The increasing sophistication of electronic countermeasures systems poses many problems. Among them—how to cool vital components at the environmental and operational extremes encountered in sonic and supersonic aircraft.

For the Sperry countermeasures system, a new airborne active cooling system—capable of dissipating 47KW in a 74-lb. package—was developed by Vickers using 3M Dielectric Coolant FC-75.

This most stable of all fluids offered to electronics has high electric strength of 37KV. It is self-healing, and maintains electric strength after repeated high voltage arcing. It pours at —148°F and boils at 212°F at one atmosphere . . . ideally suited for evaporative cooling.

Compatible with most materials, FC-75 is non-corrosive, non-flammable, non-toxic, non-explosive and odorless. It is thermally stable in excess of 800°F, and will not form sludges or gums under extremely rigorous conditions. These properties make it ideal as a coolant.

Investigate the remarkable properties of 3M inert fluids in terms of your own product design, miniaturization and performance problems. For free literature, write to 3M Chemical Division, Dept. KAR-80, St. Paul 6, Minn.

CHEMICAL DIVISION

MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

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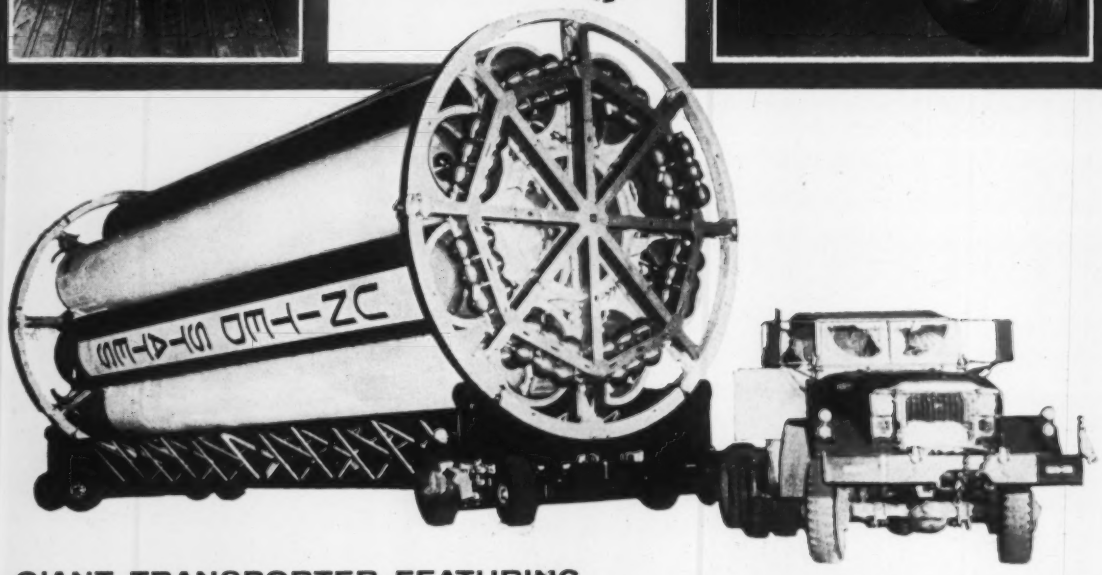

GIANT TRANSPORTER FEATURING ACIPCO "WALKING BEAM ASSEMBLIES" WILL HELP...

Saturn's conquest of space

The moment draws near when America's Saturn rocket will thunder into space. But in the meantime, elaborate ground preparations are now taking place.

From the N.A.S.A. Marshall Space Flight Center in Huntsville, Alabama, via a circuitous land and water route to the launching site, the missile and its valuable cargo will be gently cradled on the huge transporter shown here. Acipco walking beam assemblies (upper left) are vital parts of this transporter.

These rugged assemblies are constructed of high strength alloy steel and comprise centrifugally spun and statically cast component parts . . . all produced at Acipco. Also, all precision machining and intricate fabrication work were done by skilled Acipco personnel.

While your tubular product application may not be destined for outer space, Acipco's production "know how" and complete "under one roof" facilities can assist you, too. Your inquiry is invited.

ACIPCO

SPECIAL PRODUCTS

DIVISION OF ACIPCO AMERICAN CAST IRON PIPE CO.

BIRMINGHAM 2, ALABAMA

For more information, turn to Reader Service card, circle No. 388

Special fastener does it better at half the cost

OLD BOLT

The sleeve-type bolt was used as a steel strapping handle for railroad cars. Not only was the weld expensive, but the part had inadequate strength for the holding of heavier loads.

NEW BOLT

Bethlehem fastener engineers designed this forged-eye bolt. A greatly increased strength resulted from both the new design and the use of a heavier material . . . *at half the cost of the old style bolt!*

Our ability to redesign fasteners is just one example of how our fastener engineers can study your problem. Perhaps a minor change—or a completely different design—can do your job better . . . and at lower cost. Bethlehem makes just about every type of steel fastener specialty—forgings, rods, bolts, nuts, and stampings.

Just send us a rough pencil sketch or drawing of the part you need, indicating dimensions. After our fasteners engineers have studied it, we'll give you our honest appraisal of what we can do for you. If we can't recommend a practical solution, we'll say so. But if we can help you, and you are fully satisfied with our estimate, we're prepared to give you fast delivery. Just phone our nearest sales office.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

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This Sandusky Centrifugal Casting—one of four produced for Westinghouse Atomic Equipment Department—meets radiographic, intergranular corrosion, and all other rigorous chemical and physical tests.

ONE SANDUSKY CENTRIFUGAL CASTING ...makes 4 giant stator shells

Specified by Westinghouse for 4 canned motor pumps soon to be integral parts of reactor system in Yankee Atomic Electric Plant in Rowe, Massachusetts

One king-size 17-ton Sandusky casting supplied the main motor bodies (stator shells) for the four pumps being built by Westinghouse, each to handle 23,600 g.p.m. of pressurized water through the reactor core.

The 25-foot-long Sandusky casting was centrifugally spun of a modified CF-8 (Type 304 L) stainless steel, then machined by Sandusky to a 3" wall thickness, 31½" on the O.D. This huge casting was hydrostatically tested to 3800 psi before being sectioned into four 68" lengths.

These stator shells represent another *new and exacting application* for Sandusky Centrifugal Castings—which may offer a practical and economical answer to *your* cylindrical requirements also. They are available in diameters from 7" to 54"—in lengths up to 33 feet—in heat- and corrosion-resistant stainless, carbon and low-alloy steels and a wide range of copper-base and nickel-base alloys.

Let us show you how Sandusky Centrifugal Castings can help solve your cylindrical problems. Write to us at Sandusky, Ohio.

SANDUSKY S **CENTRIFUGAL CASTINGS**

FOUNDRY & MACHINE CO.

SANDUSKY, OHIO Stainless, Carbon, Low-Alloy Steels—Full Range Copper-Base, Nickel-Base Alloys

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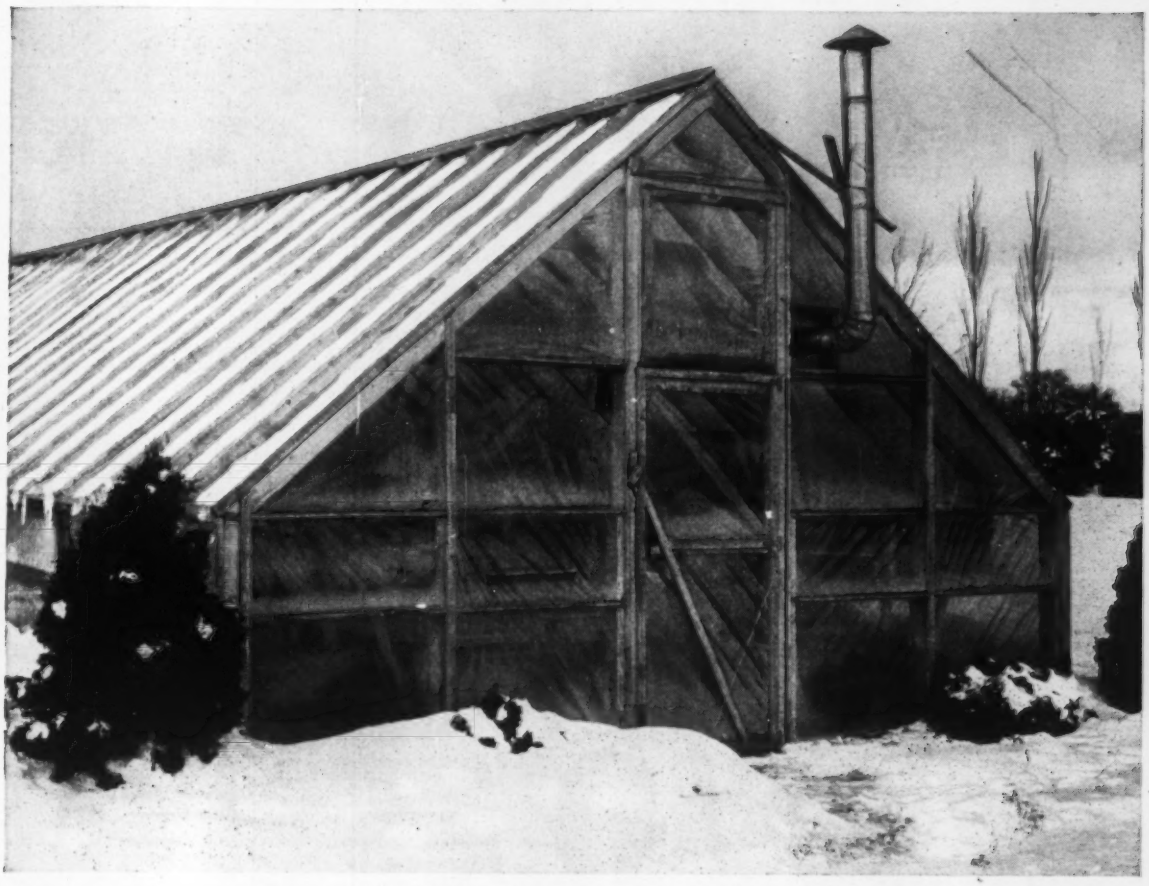

Durable glazing film of MYLAR® W protects greenhouses . . . even in sub-zero weather

Can the unique combination of properties found in "Mylar" help solve your design problems?

"Mylar" retains strength at -60° C.
Refrigeration chamber punch test proves that "Mylar" retains its high strength even when exposed to severest cold.

"Mylar"* polyester film is a tough, flexible engineering material. A modification of the film—"Mylar" W— withstands ultraviolet light from sun for a minimum of 4 to 7 years**...far longer than conventional plastic films. "Mylar" retains its toughness and flexibility in spite of temperature extremes from -60° to 150°C.

"Mylar" has an average tensile strength of 20,000 psi, a dielectric strength of 4,000 volts per mil for 1 mil film, plus excellent resistance to most chemicals and moisture.

On an area basis, tough, thin "Mylar" often costs less than heavier, conventional materials. "Mylar" can be laminated, embossed and metalized, punched or coated. The film won't embrittle with age. "Mylar" is available in roll or sheet form in a wide range of gauges.

Find out how the combination of properties in "Mylar" can help you solve knotty design problems, improve product performance or cut cost. Write today for our new booklet containing detailed information on properties and applications. E. I. du Pont de Nemours & Co. (Inc.), Film Dept., Room M-9, Wilmington 98, Delaware.

*"Mylar" is Du Pont's registered trademark for its brand of polyester film.
**4-year life applies to constant exposure at 45° angle facing south; 7-year to vertical exposure.

DU PONT
REG. U.S. PAT. OFF.
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

DU PONT MYLAR® POLYESTER FILM

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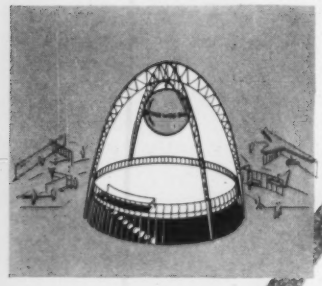


Theme Tower Symbol of the 1960 Metal Show

Why we plan to be in Philadelphia October 17

"ASM brings together in one place and at one time the year's most important developments in the technical and practical aspects of the metals industry. Never have I left a show without several ideas for applications of materials, equipment or processes in my engineering work. The 1960 Metal Show promises me more 'take home' than ever."

Raymond J. Hibbeln,
Dept. Chief, Product & Development Engineering
WESTERN ELECTRIC COMPANY

"The problem of keeping abreast of new developments in today's rapidly changing technology is always difficult. The Metal Show, through its audio-visual presentations of current advances in knowledge, presents a time-condensed package for those interested in metals engineering and processing."

R. F. Thomson, Head
Metallurgical Engineering Dept.
Research Laboratories
GENERAL MOTORS CORP.

Design engineering experts know the value of the 1960 Philadelphia Metal Show—how stimulating it will be—and that's why they plan to attend. They know that new emphasis on the essential metals and materials, processes and techniques will make the 1960 Show more valuable than ever before . . . providing some 300 exhibits and 250 technical papers. Attendance is a sound investment for you and your company!

"Our materials engineering responsibility extends from A (Aluminum) to Z (Zirconium). We plan to take to Philadelphia in October a series of questions concerning specific problems that need resolution at that time. The people that have the answers to these problems will be there as vendors, authors, or co-workers."

G. F. Kappelt
Chief Metallurgist
BELL AIRCRAFT CORP.

NATIONAL METAL CONGRESS and EXPOSITION

Philadelphia Trade & Convention Center • October 17-21

Sponsored by the AMERICAN SOCIETY FOR METALS *Metals Park • Novelty, Ohio*

Cooperating Activities: The Metallurgical Society of AIME; Society for Non-destructive Testing, Inc. Associations presenting technical sessions in cooperation with ASM: Metal Powder Industries Federation; Metal Treating Institute; Ultrasonic Manufacturers' Association; Industrial Heating Equipment Association; Special Libraries Association—Metals Division; American Society for Testing Materials—Committee B-9; and extensive research and engineering programs of the American Society for Metals, and ASM Seminars.

Show Hours: Monday, Noon - 6 p.m.; Tuesday, Noon - 10 p.m.; Wednesday, Noon - 10 p.m.; Thursday, 10 a.m. - 6 p.m.; Friday, 10 a.m. - 6 p.m.

For more information, turn to Reader Service card, circle No. 449

ENGINEERING & DESIGN

...AT A GLANCE

Coatings of certain polar organic compounds greatly increase the fatigue strengths of steel, magnesium and copper-beryllium alloys. Research shows that polar compounds such as octyl alcohol form tightly packed monolayers on metal surfaces that act as a barrier to water and oxygen molecules.

Source: National Bureau of Standards, Office of Technical Information, Washington 25, D. C.

A technique for studying superconductivity in materials has been developed. The new method uses an ingenious combination of magnetic and optical effects to make visible the changes taking place in the "intermediate state," a condition in which portions of a material are superconductive and portions normal. The ability to observe this state is expected to speed the development of practical electronic devices using superconductivity.

Source: W. DeSorbo, Research Laboratory, General Electric Co., Schenectady, N. Y.

Cause of the severe oxidation of columbium at temperatures as low as 750 F has been discovered. Recent research shows that continued nucleation and growth of porous columbium pentoxide causes a continuously refreshed surface of columbium to be exposed to oxygen.

Source: National Bureau of Standards, Office of Technical Information, Washington 25, D. C.

A new finding on the fracture of solids indicates that edge dislocations of similar sign behave exactly the opposite at high speeds than at low speeds. At near-sound speeds, edge dislocations of the same sign attract each other, and those of unlike sign repel each other. Thus a fracture can start when a large number of edge dislocations of the same sign are forced together to form a crack.

Source: J. Weertman, Northwestern University, Evanston, Ill.

Tear strength of resin-treated cotton fabrics can be improved by making subtle changes in fabric geometry, recent research indicates.

Source: Fabric Research Laboratories, Inc., 1000 Providence Hwy., Dedham, Mass.

Metal pipes can now be fatigue tested in a few minutes—five or six times faster than by previous methods—as the result of a new method. An arrangement of weights attached to an air-filled pipe section and to an electric motor induces a sympathetic vibration in the pipe at its natural frequency. The pipe bends itself back and forth several thousand times a minute until a tiny crack appears. Air leaking out of the crack causes all machinery to stop, and a timer shows how long it took for the pipe section to wear out.

Source: Chemetron Corp., 224 E. Broadway, Louisville, Ky.

An experimental electrolytic gas cell generating an oxygen-hydrogen gas mixture is a promising fuel source for explosive metal forming operations and high temperature welding and cutting torches. Used in welding torches, the burning gases can produce temperatures above 3600 F. When exploded, the mixture creates pressures 10 times greater than the starting pressure.

Source: J. McCallum, Battelle Memorial Inst., 505 King Ave., Columbus 1, Ohio.

More companies report savings

by re-designing with Ryertex-Omicron PVC

Improves production and performance

More than two years ago one of the largest manufacturers of spraying equipment switched to nozzles machined from Ryertex®-Omicron PVC bar stock. The manufacturer selected Ryerson's PVC because of its superior chemical resistance (the nozzles are used to spray hundreds of corrosive solutions—acids, salts, liquid fertilizers, etc.) and because it can be run through automatics like steel, without preliminary grinding, since it is produced to unusually close tolerances—±.005 for sizes under 1″, and ±.003 for 1″ and over.

Resists attack of fumes—forever

A Pennsylvania metals plant has found Ryertex-Omicron PVC sheets perfect for the exhaust system above a series of pickling tanks. After more than two years this company reports "complete satisfaction"—and actually Ryerson's PVC will *never* corrode . . . *never* need replacement. In addition, good fabricating qualities and light weight made construction and installation of the extensive system much easier.

Withstands abrasive-corrosive action

A Wisconsin electric company found that metal chutes needed frequent replacing because they couldn't withstand the abrasive-corrosive action of coal. At the suggestion of a Ryerson representative, ⅛″ sheets of Ryertex-Omicron PVC were fastened to the steel chutes with flat head screws. No replacement problem now—and it has been more than a year and a half since installation of the Ryertex-Omicron PVC.

Stands up under pressure

In the disposal system of a Midwest steel mill, spent acids are pumped 70′ up a conveyor tower—creating pressure that caused the first installation of another plastic pipe to burst repeatedly. The problem was permanently solved several years ago with the installation of Ryertex-Omicron PVC pipe. Our PVC has superior physical properties—for example, compare maximum operating pressures at 68° F.:

Standard Schedule 40 1″ pipe	325 psi
Extra Heavy Schedule 80 1″ pipe	435 psi
Double Extra Heavy Schedule 120 ½″ pipe	650 psi

And, Ryertex-Omicron PVC resists hundreds of corrosive solutions and gases, including the sulphuric acid present in this application.

Lowers costs three ways

A Midwest vinegar company is switching to lines of Ryertex-Omicron PVC at all its plants on the basis of an installation at its newest plant, built a little more than a year ago. Ryerson's PVC reduced by two-thirds the initial cost of piping at this plant. It has given, and will continue to give, absolute resistance to the acid solutions, and only one man is needed to change the entire system of lines when switching product runs.

These examples illustrate only a few of the many advantages of Ryertex-Omicron PVC. It resists more than 200 corrosive liquids and gases . . . will not weather, rot or age . . . is available in sheets, rod, pipe, tubing, valves and fittings. Send for our Bulletin 80-3.

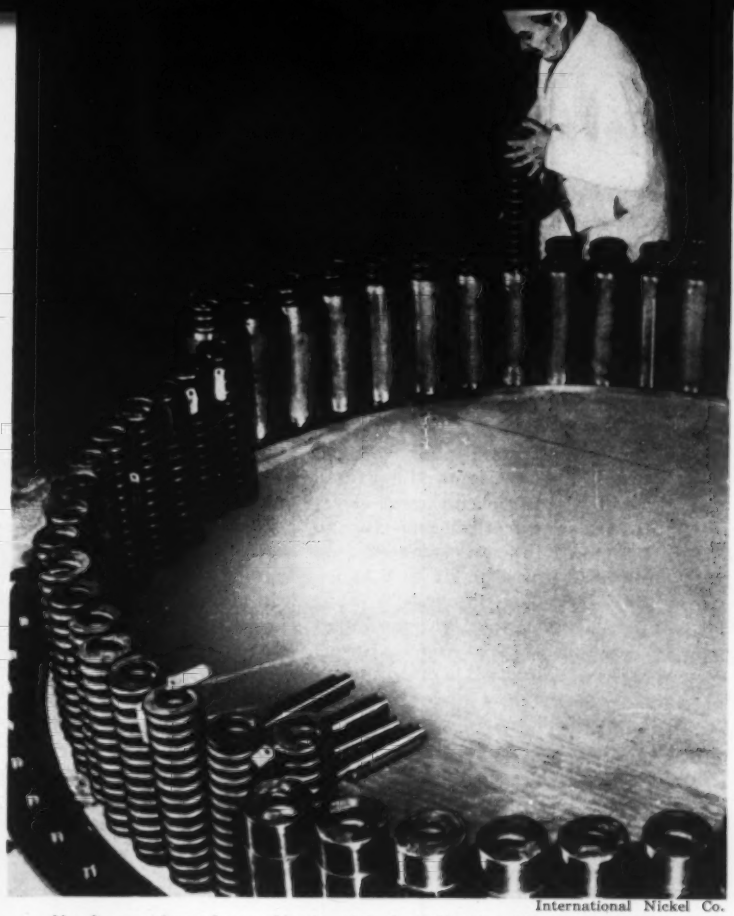
INDUSTRIAL PLASTICS AND BEARING DIVISION

RYERSON STEEL

Joseph T. Ryerson & Son, Inc., Member of the INLAND Steel Family

PLANT SERVICE CENTERS: BOSTON • BUFFALO • CHARLOTTE • CHICAGO • CINCINNATI • CLEVELAND • DALLAS • DETROIT • HOUSTON • INDIANAPOLIS
LOS ANGELES • MILWAUKEE • NEW YORK • PHILADELPHIA • PITTSBURGH • ST. LOUIS • SAN FRANCISCO • SEATTLE • SPOKANE • WALLINGFORD

For more information, turn to Reader Service card, circle No. 421



International Nickel Co.

***Nuclear submarine valve** is critical application for compression spring.*

Here is a comparison of . . .

High Temperature Alloys for Compression Springs

by J. M. Thornton, *Vice President, Duer Spring & Mfg. Co., Inc.*

■ The following pages offer a guide to the selection of materials for compression springs to be used at high temperatures.

Information and data presented are the result of high-temperature load-loss tests conducted on hot and cold wound springs made of eight different alloys. The tests were run 168 hr at 700 F under a stress of 77,500 psi (corrected value). Load-loss results are summarized in Table 1.

The next two pages outline the major characteristics and relative cost of each alloy tested. Both room temperature properties and results of the high temperature load-loss test are discussed.

Pages 114-115 give details on alloy composition, heat treatments, specimen design and test procedure.

From the data it would appear that Inconel X is the most satisfactory material for hot wound springs insofar as relaxation at high temperatures and corrosion resistance are concerned. For cold wound springs, Haynes 25 alloy seems the most satisfactory in resistance to high temperature relaxation, though a longer test might have favored Inconel X.

TABLE 1—SUMMARY OF LOAD LOSS RESULTS (%)

HOT WOUND SPRINGS	
Inconel X	2.7-8.3
17-4 PH	17.7-18.9
9% Tungsten	12.5-27.1
2% Tungsten	14.3-19.1
18% Tungsten	15.7-31.0
COLD WOUND SPRINGS	
Haynes 25	0.89-1.78
Inconel X	3.1-4.9
9% Tungsten	11.5-12.0
Inconel	18.7-19.1
17-7 PH	23.5-27.1
Type 302	28.9

Compression springs widely used in industry

In nuclear power plants, such as the new one at Shippingport, Pa., as well as in atomic reactors for submarines and future aircraft carriers, compression springs are essential for use as blanket hold-down springs, control rod mechanisms and mechanical safeguards.

One of the largest and most important applications of compression springs is safety valves. Ranging widely in size, these valves are used in steam power plants, in the chemical process industries—in almost all industries, in fact.

Hot wound springs range from 7/16 to ½ in. in dia or larger, depending on spring index. Cold wound springs are smaller in diameter.

How the alloys compare:

Room temperature properties ***Fabricability*** ⬇	***Relaxation at 700 F*** ⬇	***Cost*** ⬇
INCONEL X NICKEL-CHROMIUM ALLOY This material can be used successfully for both small cold-wound springs and heavy hot-wound springs. Current recommendations dictate the use of No. 1 temper wire that has been grain-coarsen-annealed prior to final reduction. It is easily worked and gives consistent response to age hardening with little distortion during heat treatment. Hot wound springs can be hot set at 1600 to 1750 F. Setting in the low ductility range from 1200 to 1500 F should be avoided; setting below 1200 F is impractical due to the stiffness of the alloy. Hot wound springs that have been heat treated exhibit relatively low resistance to set at room temperature. If the operating stress is low enough so that set can be removed at room temperature, the alloy will yield much less than other materials tested. However, the room temperature properties of the tungsten steels—particularly resistance to set—are better than those of Inconel X. Tests at –320 F indicate that Inconel X had the best spring properties at subzero temperatures.	**Hot wound.** Inconel X is the best high temperature alloy for hot wound springs from the overall standpoint of relaxation at elevated temperatures and resistance to corrosion. It showed consistently low load losses of 2.7 to 8.3%. **Cold wound.** Haynes 25 alloy showed lower relaxation values than Inconel X at 700 F. Nevertheless, the load loss of Inconel X was consistently under 5%. Recent relaxation data compiled by others over more prolonged periods of time indicate that Inconel X has the highest initial load loss, but a lower rate of load loss with prolonged time under stress at high temperature than Haynes 25 alloy. Had the tests been conducted for 28 days or longer, instead of 14 days, it is believed that Inconel X would have shown the lower total relaxation.	As the size decreases to ⅛ in., Inconel X achieves a cost advantage over the tungsten steels. In the heavy sizes for hot coiling, Inconel X costs considerably less per pound than it does in the light sizes that are cold coiled. Inconel X springs are thus competitive in cost with 18% and 9% tungsten steel springs in diameters of more than ½ in. or less than 3/16 in.
HAYNES 25 COBALT ALLOY Haynes 25 alloy can only be cold wound, limiting its use to spring diameters less than about ½ in. The alloy has a higher creep rate than Inconel X and is considerably less ductile than all other materials in the 35% cold reduced condition. This restricts its use to springs of fairly large index. Breakage was encountered in coiling Haynes 25 to 0.148-in. dia to an index of 4.25, but 0.187-in. dia wire was successfully coiled to an index of 4.5. As a result, a minimum index of 5 is recommended.	**Cold wound.** This alloy had the lowest load loss of all cold wound spring materials under the test conditions. A prolonged test period might eventually have shown Inconel X with the lower load loss.	This is the most expensive material tested for cold wound springs. However, when it comes to manufacturing costs, it has the offsetting advantage of a relatively short heat treating cycle.
TUNGSTEN STEEL ALLOYS Of the three alloys—2%, 9% and 18%—only the 9% one was tested for both cold wound and hot wound springs. The others were tested as hot wound springs only. All three grades should be confined to applications where magnetic materials can be used and where corrosion resistance is not a critical problem. *Continued on next page*	**Hot wound.** None of the three grades gave particularly good results at 700 F, although some heat treatments were better than others. The data would indicate that the use of these alloys should be limited to temperatures lower than 700 F. There appears to be *Continued on next page*	Though competitive with Inconel X at 3/16-½-in. dia, all three grades of tungsten steel alloys cost more than 17-4PH. Therefore, the 18% and 9% grades would *Continued on next page*

Room temperature properties of all three alloys are considerably better than those of Inconel X. In resistance to set at room temperature, the two higher tungsten grades are better than 17-4PH and the 2½% grade is about equal to 17-4PH. Therefore, the tungsten grades are valuable when high stresses are to be encountered at room temperature.	no advantage in resistance to heat set for the more expensive 18% grade over the 9%, and only a slight advantage for the 9% over the still cheaper 2½% grade. **Cold wound.** The 9% tungsten steel alloy had considerably higher load loss than Inconel X. It should be limited to applications where the continuous operating temperature is lower than 700 F and where the wire diameter required is 3/16 in. or larger (under that size there is no cost saving over the superior Inconel X).	be advantageous only when the room temperature stresses will be beyond the range of 17-4PH.
INCONEL Because it is not age hardenable, spring-temper Inconel cannot be hot wound into springs and is therefore used only for cold wound springs. It is best used where the material must be nonmagnetic or where the corrosion resistance of a nickel-base alloy is required. In the presence of many corrosive agents, such as chlorides, it surpasses both 302 stainless and 17-7PH in corrosion resistance. Inconel's room temperature physical properties, however, are not as good as those of Inconel X or the two stainless steel alloys.	**Cold wound.** The test results suggest that grain-coarsen-annealed Inconel should be used, and service limited to temperatures under 700 F. Two of the three springs gave load losses of 18.7 and 19.1%. The third gave a low loss of 6.7%. This low value is believed to be associated with coarse grain material which has recently been shown to exhibit lower relaxation than fine grain material. Although all springs tested were made of wire from the same heat, it is possible that different bundles of wire were given different final process anneals.	Inconel costs more than stainless 17-7PH alloy or type 302.
STAINLESS STEEL 17-7PH ALLOY This alloy was tested only for cold wound springs. It is magnetic both before and after heat treatment. It is easily worked and consistently responds to age hardening without distortion. At room temperature, 17-7PH in the hardened condition far exceeds other corrosion resistant materials in its ability to resist set at high stresses. Its room temperature physical properties are better than Inconel's, its corrosion resistance not as good.	**Cold wound.** Load loss results were relatively poor. It is believed that the heat treatment used—the recommended one—may not be the most effective for the purposes of this test. Hot wound springs of 17-4PH stainless (same alloy family) gave much better results.	Less than Inconel.
STAINLESS STEEL TYPE 302 This alloy is used only for cold wound springs. Despite its limitations for 700 F service, it is still the least expensive, most readily available and best all-round stainless material for springs. In the lighter sizes, type 302 resists room temperature set almost as effectively as music or alloy steel wire. At temperatures from 400 to 500 F there is no more advantageous material for compression springs. The only limitation to consider: its corrosion resistance in many media is inferior to that of spring-temper Inconel.	**Cold wound.** Of the materials tested at 700 F, stainless 302 gave the poorest results. It is recommended that its use be limited to temperatures somewhat lower than 700 F. Otherwise, its other advantages will often recommend it	It is considerably less expensive, both in material and manufacturing costs, than other materials tested. Cheaper than three tungsten grades, it should be preferred unless room temperature stress is beyond its range.

TABLE 2—COMPOSITION OF SPRING ALLOYS TESTED (%)

Alloy ↓	Ni	Cr	Fe	Cu	Al	Ti	Mn	Si	S	C
Inconel X	70.0 min	14.0-17.0	5.0-9.0	0.50 max	0.4 -1.0	2.0-2.5[b]	1.0 max	0.5 max	0.015 max	0.08 max
Haynes 25 Alloy	9.0-11.0	19.0-21.0	3.0 max	—	—	—	1.0-2.0	1.0 max	—	0.05-0.15
9% Tungsten (H22[a])	—	3.25-3.75	Bal	—	—	—	0.10-0.30	0.20-0.40	0.025 max	0.30-0.35
2½% Tungsten (51[a])	—	1.50-1.80	Bal	—	—	—	0.10-0.30	0.20-0.35	0.03 max	0.50-0.55
18% Tungsten (T1[a])	—	3.75-4.25	Bal	—	—	—	0.10-0.30	0.25-0.40	0.03 max	0.65-0.75
Inconel	72.0 min	14.0-17.0	6.0-10.0	0.50 max	—	—	1.0 max	0.5 max	0.015 max	0.15 max
17-7 PH	6.50-7.75	16.0-18.0	Bal	—	0.75-1.5	—	1.00 max	1.00 max	0.03 max	0.09 max
Type 302	8.0-10.0	17.0-19.0	Bal	—	—	—	2.0 max	1.0 max	0.030 max	0.15 max
17-4 PH	3.0-5.0	15.5-17.5	Bal	3.0-5.0	—	—	1.00 max	1.00 max	0.03 max	0.07 max

[a]AISI designation. [b]For cold wound springs. For hot wound springs, 2.25-2.75.

Here are details on:

- ***Alloy composition***
- ***Heat treatments***
- ***Specimen design***
- ***Test procedure***

Compositions of the alloys tested are given in Table 2; conditions and heat treatments of the specimens in Table 3. Costs of the spring materials, in various diameters and lot sizes, are compared in Table 4.

Specimen design

The cold-wound springs were all made of ¼-in. dia wire to the same design. Each had an o.d. of 2 in., six total coils, four active coils with ends squared and ground. Free length was varied

TABLE 3—CONDITIONS OF ALLOYS AS TESTED

Alloy	Wound[a]	Condition When Coiled	Heat Treatment	Hardness
Inconel X	Hot	Hot rolled, annealed, centerless ground	Hot coil at 2000 F, air cool after coiling; hold 2 hr at 1600 F, air cool; hold 16 hr at 1350 F, air cool	36-37 R_c
	Cold	No. 1 temper	16 hr at 1350 F	41-43 R_c
Haynes 25	Cold	35% cold reduced	4 hr at 1025 F	50-51 R_c
9% Tungsten	Cold	Cold drawn, annealed	Preheat at 1625 F, high heat at 2000 F, quench in oil to 600 F, then air cool to 150 F; double draw 2½ hr at 1025 F, 2½ hr at 1125 F	48 R_c
	Hot	Hot rolled, annealed	Hot coil at 2000 F, air cool; preheat 1500 F, high heat at 2100 F, oil quench to 600 F, then air to 150 F; draw 2½ hr at 1150 F	49 R_c
			Hot coil at 2000 F, anneal at 1600 F; preheat at 1625 F, high heat at 2000 F, oil quench to 600 F, then air to 150 F; double draw 2½ hr at 1025 F, 2½ hr at 1125 F	48 R_c
			Same as above except draw: double draw 2½ hr at 1050 F, 2½ hr at 1175 F	45 R_c
2% Tungsten	Hot	Hot rolled, annealed	Hot coil at 2000 F, air cool; preheat at 1250 F, high heat at 1775 F, oil quench to 600 F, then air to 150 F; draw 1 hr at 1050 F	44-46 R_c
			Hot coil at 2000 F, anneal at 1500 F; preheat at 1125 F, high heat at 1650 F, quench in oil to 600 F, then air to 150 F; double draw 2½ hr at 800 F, 2½ hr at 975 F	44 R_c
18% Tungsten	Hot	Hot rolled, annealed, centerless ground	Hot coil at 2000 F, air cool; preheat at 1575 F, high heat at 2250 F, quench in oil to 600 F, air to 150 F; draw 3 hr at 1250 F	52-54 R_c
			Hot coil at 2000 F, anneal at 1600 F; preheat at 1625 F, high heat at 2200 F, quench in oil to 600 F, then air to 150 F; double draw 2½ hr at 1000 F, 2½ hr at 1225 F	49 R_c
			Same as above except draw: double draw 2½ hr at 1000 F, 2½ hr at 1250 F	45 R_c
Inconel	Cold	Spring temper	1 hr at 900 F	38.5-39.5 R_c
17-7 PH	Cold	Condn C	1 hr at 900 F	51-52 R_c
Type 302	Cold	Spring temper	1 hr at 900 F	41-42 R_c
17-4 PH	Hot	Centerless ground, condn A	Hot coil at 2000 F, air cool; harden 1 hr at 900 F	43-44 R_c

[a]Wire size: hot, ⅝ in.; cold, ¼ in.

Cb+Ta	Co	P	W	V
0.7-1.2	1.0 max	—	—	—
—	Bal	—	14.0-16.0	—
—	—	0.025 max	9.5-10.0	0.35-0.55
—	—	0.03 max	1.75-2.25	0.20-0.30
—	—	0.03 max	17.5-18.5	0.95-1.10
—	—	—	—	—
—	—	0.04 max	—	—
—	—	0.045 max	—	—
0.15-0.45	—	0.04 max	—	—

between 2¾ in. and 3 in. to compensate for the difference in torsional modulus of the materials tested and to maintain a reserve deflection between the loaded height and the solid height of the spring.

The hot wound springs were all made of ⅝-in. dia bar to the same design. Outside diameter was 5 in. and each spring had seven coils, five active. Ends were squared and ground. Free length was varied between 7 in. and 8 in. for the reasons cited above.

Loading procedure

After heat treatment, the springs were cold pressed three times under a specific load (250 lb for cold wound, 1400 lb for hot wound). This procedure is commonly used by spring manufacturers in testing springs and is done to eliminate set at room temperature before running tests at elevated temperatures. By cold pressing beyond the proportional limit of the material, allowable stress is increased approximately 10%. (There is some controversy as to whether this practice, when applied to high temperature springs, may not be actually contributing to increased relaxation, since cold work generally affects relaxation adversely.)

Following cold pressing, the springs were released, again compressed under the same load (225 or 1400 lb), and clamped at this loaded height. This load, by calculation, put the springs under a room-temperature torsional stress of 77,500 psi, corrected for curvature. Calculated stress was not corrected for the drop in torsional modulus of elasticity from room temperature to 700 F, but change in modulus was assumed to be of limited value in the general comparisons to be made.

The springs were then placed in a recirculating draw furnace and held at 700 F for 168 hr. At the end of this period, the springs were allowed to air cool. Clamps were removed and free length of the springs was recorded.

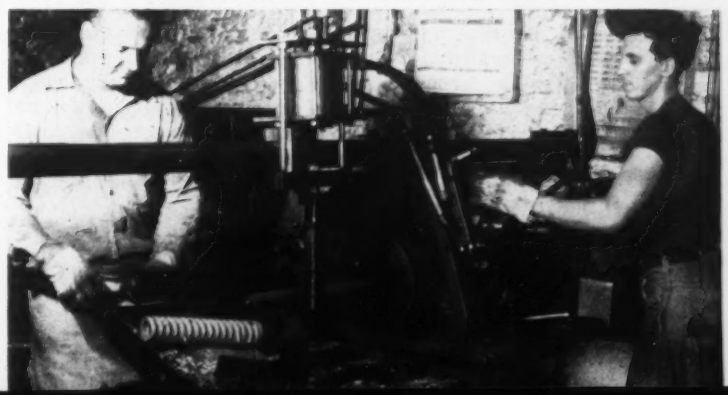
The springs were tested for load, at room temperature, at the height at which they were previously clamped for the heat exposure test. Load and deflection were measured within 48 hr after removing the springs from the furnace.

TABLE 4—MATERIALS AND MANUFACTURING COSTS

Alloy	Lot No.[a]	Cost of Material, $	Cost of Mfg. & Ht Tr, $	Total Cost, $
HOT WOUND SPRINGS				
Inconel X	1	259	200	459
	2	135	170	305
17-4 PH	1	111	70	181
	2	65	60	125
9% Tungsten	1	179	225	404
	2	94	180	274
2% Tungsten	1	91	150	241
	2	49	125	174
18% Tungsten	1	231	250	481
	2	121	200	321
COLD WOUND SPRINGS				
Haynes 25	3	364	100	464
	4	120	90	210
Inconel X	3	174	120	294
	4	44	110	154
9% Tungsten	3	53	181	233
	4	49	170	219
Inconel	3	52	50	102
	4	13	20	33
17-7 PH	3	35	50	85
	4	11	20	31
Type 302	3	26	50	76
	4	8	20	28

[a]Lot No. 1: 5 springs; wire dia 1 in.; 20 lb per spring. Lot No. 2: 10 springs; wire dia ⅝ in.; 5 lb per spring. Lot No. 3: 25 springs; wire dia ¼ in.; 1 lb per spring. Lot No. 4: 25 springs; wire dia ⅛ in.; ¼ lb per spring.

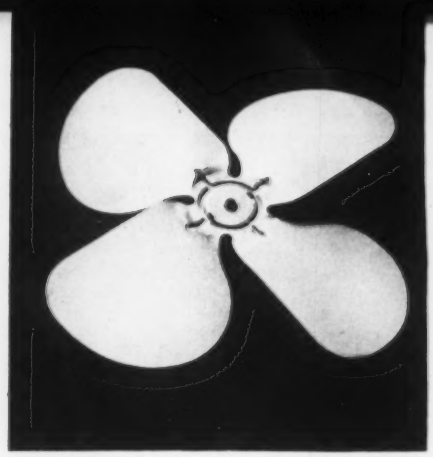
Hot wound spring *is removed from its mandrel in the coiling machine. Springs of ½-in. dia or larger are generally hot wound.*



Chromate Conversion Coatings for...

Corrosion protection

Outboard motor of aluminum. Chromate coating also provides good paint base.



Good appearance

Fan blade of aluminum. It retains attractive appearance for long periods.

by C. W. Ostrander,
Technical Director,
Allied Research Products, Inc.

■ Because of their good combination of properties chromate conversion coatings have achieved rapid acceptance for treating most common nonferrous metals—zinc, cadmium, aluminum, magnesium, copper and silver. In addition to the advantages listed above the coatings are quite inexpensive, since they use inexpensive materials and are readily applied in tanks. Electroplated coatings, for example, can be treated easily right after the final rinsing operation; most other surfaces usually just require five simple processing steps.

Properties of the coatings make them versatile

Corrosion resistance

Chromate conversion coatings are particularly valuable in preventing corrosion in salt spray and marine environments, and in high humidity stale air environments, such as those found in storage. They also provide excellent protection against tarnishing, staining, finger marking, and other conditions tending to produce surface oxidation.

The color of chromate conversion coatings varies with the treatment used. Maximum corrosion protection is obtained on zinc and cadmium surfaces by using olive drab or dark bronze coatings which also have a fairly pleasing appearance. Maximum corrosion protection on other metals is obtained by using yellow to brown coatings. Olive drab coatings, in particular, are popular for military applications because of their high corrosion protection coupled with their nonreflectivity.

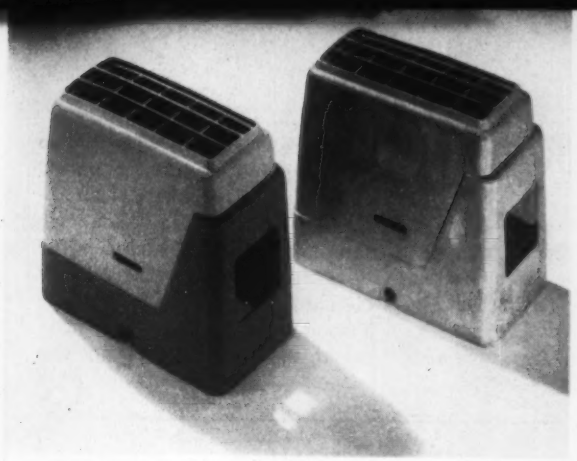
The lighter, iridescent, yellow-type coatings provide medium protection and are widely used for corrosion protection where improved appearance is not needed. Clear, bright, chemically polishing-type coatings generally provide the least protection. Coatings of this type for zinc and cadmium have been widely used to simulate nickel and chromium electroplates and are mainly used for decoration rather than corrosion protection. However, they can be finished with a clear organic coating where additional corrosion protection or abrasion resistance is needed.

Although the protective value of chromate conversion coatings is generally proportional to their thickness, thin, iridescent yellow coatings often will give equal or better corrosion protection than heavy brown coatings, particularly in accelerated salt spray tests. Also, heavy coatings may be quite soluble in aqueous solutions, their protective hexavalent chromium constituent readily leaching out and away. In contrast, thinner coatings contain less soluble hexavalent chromium and probably a higher concentration of insoluble trivalent chromium; they appear to be less affected by leaching in aqueous solutions.

Chromate conversion coatings can become dehydrated and lose their protective properties when exposed to sunlight for prolonged periods. It is not known as yet if this effect is due to ultraviolet light or heat from the sun.

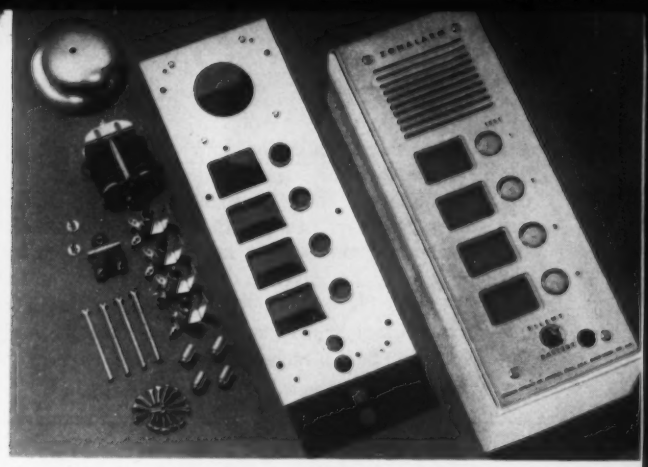
Appearance

Some of the colors available for chromate conversion coatings have been mentioned above. If required, the heavy olive drab and yellow coatings for zinc, cadmium and aluminum can be dyed various colors. In addition, some of the clear chromates for zinc surfaces are absorptive to dyes and can thus be obtained in attractive pastel colors. In the past dyed colors were mainly used for identification purposes since they were not lightfast. However, in recent years very satisfactory finishes,



Paint base

Projector housing of zinc or aluminum. Chromate coating also provides corrosion protection.



Electrical conductivity

Burglar alarm electrical components of zinc-plated steel (left). Chromate coating also improves appearance and corrosion resistance of zinc-plated chassis (middle) and paint bond on sides of housing (right).

particularly for indoor use, have been obtained with clear bright coatings dyed in pastel shades and coated with clear lacquers.

Paint bonding characteristics

Chromate conversion coatings improve paint adhesion by providing a chemically clean surface with a high degree of corrosion protection. Although the coatings have good adhesion to base metals they do not promote paint adhesion through mechanical bonding, as do other metal treatments. Rather, the coatings form a nonporous barrier between the metal and the paint to produce a highly protective system. For best results they should be used with paints having good adhesive properties.

Abrasion resistance

With some exceptions, most chromate conversion coatings are soft when still wet after application and can be readily wiped off. However, when dried the coatings form a relatively hard film which will withstand a normal amount of handling and wear, but which does not add to the abrasion resistance of the coated surface. Surfaces can be cold formed with smooth dies without appreciably damaging the film.

Electrical properties

Because of their low electrical resistance, chromate conversion coatings are widely used in electronic applications, particularly on aluminum, silver, copper and magnesium. Surface resistance depends on the type and thickness of the coating, contact pressure, and the nature of the contact. The heavier chromate conversion coatings may produce slightly higher initial resistance values, but may prove more satisfactory than thinner coatings because of their greater ability to prevent the formation of corrosion products.

Solderability, weldability

Chromate conversion coatings can be soldered and welded. They facilitate heliarc welding of aluminum, and aluminum can be spot welded satisfactorily if amperage adjustments are made to allow for the slight increase in electrical resistance.

Soldering with rosin fluxes is possible on cadmium plated surfaces treated with clear, bright chromate coatings. However, clear bright coatings on zinc plates and colored coatings on zinc and cadmium have to be removed in the area of the soldered joint. Removal can be accomplished either by mechanical abrasion using an acid flux, or by increasing soldering iron temperatures so as to burn through the coating.

Many nonferrous metals can be coated

Zinc and cadmium

Two types of coatings — As shown in the accompanying table, dip-type chromate conversion coatings for zinc and cadmium can be separated into two simple groups on the basis of their acidity.

Coatings formed by type I solutions (0.0 or less to 1.5 pH) produce a clear, highly lustrous finish on zinc and cadmium electroplates which simulates a nickel or chromium electroplate in appearance. Their appearance is greatly enhanced if they are used over smooth base metal and fine grained electrodeposits. Also, plate thickness should be at least 0.2 to 0.3 mil.

The first type I process shown (No. 1) is a dilute, one-dip, process which produces a lustrous finish with a bluish cast, and requires no bleaching step. The coating is dye-absorptive and is available in many attractive pastel colors for decorative applications.

The second type I treatment listed (No. 2) uses a solution of

much greater concentration and produces a lustrous, iridescent coating. While still wet, this coating can be immersed in a solution that leaches out the soluble hexavalent chromium coating (responsible for the yellow color) and produces a clear, bright coating (No. 2A). This bleached coating provides better corrosion protection than the one-dip, unbleached coatings.

Where they are used—Type I clear bright treatments are especially valuable on zinc coated parts and are widely used for electronic equipment, appliances, auto parts, tubular furniture and hardware. They are also used to advantage on irregularly shaped zinc die castings where, in addition to providing corrosion protection, they often eliminate the need for buffing operations. When bleached the coatings also provide a good base for subsequent copper-nickel chromium plating. The

Chromate Coatings: How They Are Applied

Film formation

Chromate conversion coatings are formed by a chemical reaction that occurs when metal is immersed in a solution of chromic acid and other catalysts or activators. The nature of the coating is determined by solution pH as well as the nature of the catalyst radical(s) and its ratio to the chromium compound(s) used.

During immersion a small amount of the surface metal is dissolved which raises the pH of the solution at the surface to a point where a complex chromium gel is precipitated. Relatively little is known about the coating's composition; however, it has been established that its principal constituents are soluble hexavalent chromium and insoluble trivalent chromium, plus salts of the metal coated.

Depending on the metal treated and process used, the amount of metal dissolved is usually about 0.01 to 0.05 mil. A small amount of dissolved metal in the solution is desirable, and in some cases small amounts of metal are placed in the bath prior to production.

Solutions operated at high pH tend to produce heavy coatings. Operation at low pH often produces a chemical polishing and brightening action, particularly on zinc and cadmium, by continuously forming and redissolving the deposited coating.

Processing cycles

Treatment of freshly electroplated surfaces is comparatively simple since the chromate conversion coating can be applied following electroplating, right after thorough rinsing. Pretreatment steps are required, however, over electroplated surfaces that have aged or oxidized, and other metal surfaces such as hot dipped metals, zinc die castings, and wrought metals. With such metals it is first necessary to preclean surfaces in a hot alkaline solution, then follow up with a deoxidizing or neutralizing step (usually a mild acid dip) to remove oxide contamination.

Sequence of operations—

1. Electroplate and/or clean and oxidize.
2. Rinse in cold water.
3. Apply chromate conversion coating.
4. Rinse in cold water.
5. Rinse in warm water at 100-140 F.
6. Dry below 150 F.

Although chromate conversion solutions are generally operated at room temperature, best results are obtained between 70 and 90 F. Immersion times range from 5 to 20 sec when using chemically polishing solutions for lightweight coatings on zinc and cadmium. Depending on the process used and the metal treated, heavier coatings require from 15 sec to 3 min.

Rinsing—The cold rinse after-treatment should be thorough enough to remove any clinging solution that might tend to stain or redissolve the formed coating. The second rinse is kept warm to facilitate drying. It should not exceed 140 F, particularly for the heavier coatings, since the freshly formed chromate gel is quite soluble and will leach out in hot water. Rinsing should be done as quickly as possible to maintain maximum film thickness and corrosion protection.

Drying—As a further guarantee of corrosion protection, surfaces should be dried at room temperature or by accelerated drying below 150 F. The reason is to allow the coating to retain hexavalent chromium entrapped in a solution state. Normally, this solution can be leached out in service to provide a self-healing characteristic under humid conditions and to protect scratched or abraded areas. However, if the coating is dried above 150 F the normal water of hydration is driven off and the surface is changed from an amorphous to a crystalline structure. Thus, the hexavalent chromium is no longer in a soluble state and the protective value of the coating is greatly reduced. Naturally, if a hydrogen relief anneal is necessary for electroplated coatings it should be done before chromating.

Methods of application—Most chromate conversion coatings are applied by simple immersion using rack, bulk or strip line operations. Swabbing or brush coating can be used in special situations, particularly where small areas must be coated, as in touch-up operations.

Spraying has never been widely used; however, satisfactory coatings can be obtained by this method. The spray should be a flow of liquid covering the surface rather than a fine mist spray. It is essential that the spray solution be rinsed off immediately after the normal coating has formed in order to prevent the excess, nonreactive solution from forming powdery deposits.

Chromate conversion coatings can also be applied by an electrolytic method, using an electrolyte of water soluble compounds and other radicals operated at neutral or slightly alkaline pH. However, this type of application is limited to rack-type operation.

coatings are used on cadmium plated parts to reduce oxidation during storage and to promote solderability, particularly on electronic equipment.

Type II coatings are usually used where corrosion protection rather than decorative value is needed, e.g., military equipment and auto and appliance parts. Applicable to all zinc and cadmium surfaces, they are specified for corrosion protection and as a paint base in many government specifications. (Iridescent yellow coatings over cadmium are an exception and usually are not recommended as a paint base except in special applications.)

As mentioned earlier, heavy olive drab and bronze coatings can be dyed various colors but tend to fade when exposed to sunlight. However, they are quite satisfactory for identification of small parts.

Aluminum

Coating replaces anodizing — Because of their high corrosion protection, paint bonding properties and ease of application, chromate conversion coatings have widely replaced anodized coatings except where abrasion resistance is important. Various colors—from clear to iridescent to yellow and brown—can be produced in a single bath by varying treatment time. Degree of coloration depends on the alloy used. If necessary, yellow to brown coatings can be dyed various colors to match the color of dyed coatings on zinc and cadmium.

The corrosion protection provided by the coatings on aluminum alloys depends on film thickness and the alloy used, and is usually inversely proportional to copper and iron content. The combination of corrosion protection and low electrical resistance has proved especially useful on aluminum electronics equipment for grounding purposes and on shields and waveguides. In addition to their paint base uses, the coatings can also be used to promote the bonding of rubber and plastics to aluminum.

CHROMATE CONVERSION COATINGS FOR ZINC AND CADMIUM

Type (and sub-type) ↓	Surface	Application	Color	Operating Temp, F	Immersion Time, sec	Corrosion Protection, hr[a]
TYPE I[b]						
1[c]	Zinc and cadmium electroplates	1 dip	Clear bright with blue tint	70-100	5-20, sometimes up to 60	24-100
2	Zinc and cadmium electroplates, galvanized zinc, zinc die castings	1 dip	Yellow with bright iridescent appearance	70-100	5-20	100-200
2A	Same as above	Same as No. 2 plus acid or alkaline bleach dip	a—Clear bright b—Blue tint c—Iridescent	70-100	5-20	24-100
TYPE II[d]						
1	Same as above	1 dip	Iridescent yellow to bronze	60-90	15-45	100-200
2	Same as above	1 dip	Olive drab	70-90	15-45	100-200
3	Zinc electroplates	1 dip	Black	60-90	1-5 min	24-100

[a]Time to produce white products on zinc plate in salt spray test.
[b]Simple dip chemical polishing solutions operated at 0.0 or less to 1.5 pH and producing lustrous clear to light iridescent yellow coatings of medium corrosion resistance.
[c]Can be dyed with certain alizarine and diazo dyes in various colors while still wet during processing. Clear coatings produce pastel shades; olive drab coatings produce dark opaque colors.
[d]Nonpolishing solutions operated at 1.0 to 3.5 pH and producing medium to heavy films ranging in color from iridescent yellow to black. Olive drab and black coatings usually provide best corrosion protection.

Five-step treatment—Because of their tendency to form oxidation products it is essential that aluminum surfaces be properly cleaned before treatment. The basic sequence of operations for wrought alloys and all alloys containing less than 1% silicon is: 1) clean, using alkali etch, 2) rinse, 3) deoxidize, 4) rinse, 5) chromate treat.

A non-etch alkali cleaner can be used for polished aluminum, aircraft parts and similar applications where etching is undesirable. The treatment for sand, die and permanent mold castings, and all alloys with over 1% silicon, is essentially the same as listed except that a hydrofluoric-nitric acid pickle is substituted for the deoxidizing step.

The chromate treatment can be applied by almost any method—spray, brush, bulk, rack or swab. Swab or brush application is often very useful in touching up bare spots or abraded anodized films. In such cases the normal chromate solution is allowed to remain on the surface until a visible coating is observed; the coating is then rinsed and dried.

Magnesium

Almost all magnesium products are chemically treated at the mill to prevent corrosion during shipment and storage prior to fabrication. Chromate conversion coatings are widely used to improve corrosion resistance both before and after fabrication, and are also suitable as an adherent base for both protective and decorative

organic coatings.

Most of the treatments are available from Dow Metal Products Co. However, within the past few years proprietary treatments have been developed which show considerable promise and which appear to be unique in some respects. One type in particular has extremely low electrical resistance and has proved valuable in electronic applications.

Copper and brass

Chromate treatments for copper and its alloys are usually available as proprietary liquid concentrates or powdered compounds, and are made up and operated much as chromate treatments for other metals. Suitable modified coatings can be used as a base for nickel-chromium plating. However, most treatments are used as a final finish to produce a chemically polished, clear bright surface. Maximum brightness is obtained on fine grained homogeneous electrodeposits. A satiny, nonlustrous finish is produced on alloys with a heterogeneous structure.

Two types of nonpolishing treatments are available. One produces a heavy yellow to brown coating providing relatively high corrosion protection. The second produces a light, colorless coating which is often used 1) to eliminate spotting from electroplating, and 2) as a base for subsequent painting. Clear coatings can be readily soldered and are similar to the clear finishes used on cadmium to promote soldering.

Silver

Chromate conversion coatings are frequently applied to silver surfaces to eliminate tarnishing and corrosion. Finishes vary from clear to yellow. The degree of tarnish resistance provided depends on film thickness and is about the same as that of a good water dip lacquer. The coatings have good electrical conductivity.

For satisfactory performance on electroplates it is important that surfaces be thoroughly rinsed and neutralized to avoid any cyanide contamination. Thus, a neutralizing dip in ½% nitric acid is recommended after plating and prior to chromating.

How to evaluate the coatings

Like any other coating system, chromate conversion coatings should be evaluated to be sure they meet product standards and government and ASTM specifications. (For a complete listing of specification requirements on chromate conversion coatings see *Electroplating Engineering Handbook*, Reinhold Publishing Corp., New York, p 371.)

Visual inspection

The simplest way to evaluate a chromate conversion coating is to observe its color, uniformity of appearance, smoothness and adhesion. Depth of color is a guide to the thickness of the film which, under normal circumstances, is proportional to protective value. However, visual inspection will not show if the protective value of the film has been nullified by overheating during drying or by contamination.

Accelerated tests

Accelerated tests as well as performance tests are often used to determine the quality and protective value of chromate coatings. Prior to such tests it is recommended that the coatings be allowed to age for 12 to 24 hr.

The 20% salt spray test—ASTM B117-49T—is the only salt spray test developed in specification form and, although it has been modified to cover use of a 5% solution, the 20% solution is still generally used. Due to poor reproducibility in different boxes it is recommended that comparative tests be run at the same time as a check. Usually, specifications require that a certain number of hours elapse before corrosion products form. Also, where electroplated or hot dipped coatings are involved, the test may have to be carried out until rusting of the base metal occurs.

Humidity tests

There is no standard specification covering humidity tests for chromate conversion coatings, and tests can be operated under a variety of conditions and cycles. Actually, humidity tests are probably more meaningful than salt spray tests as they come closer to evaluating the coatings in their actual end environment.

Water tests

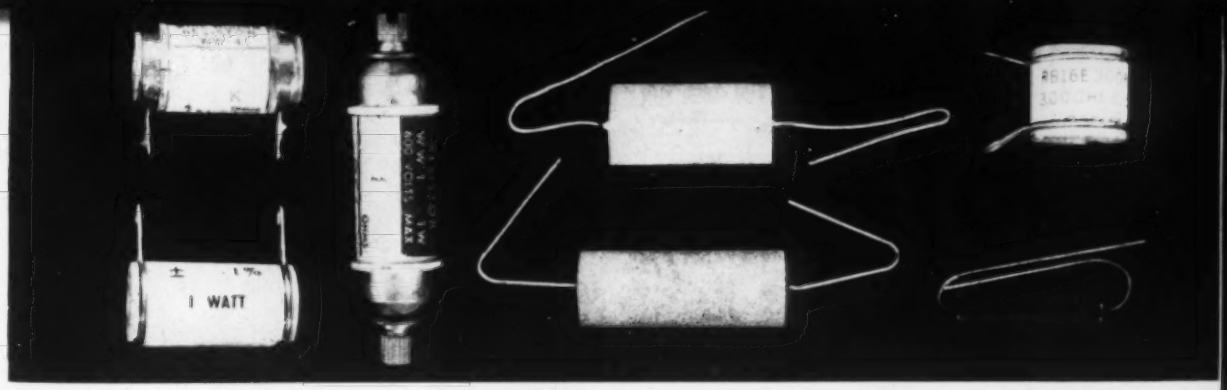
Chromate-coated zinc die castings are often tested by immersion in de-ionized or distilled water. Such tests have proved valuable in simulating the possible accumulation of water in a carburetor or fuel pump.

Coatings applied on hot dipped galvanized surfaces in strip mills are usually tested by stacking wet sheets one upon the other and weighting the top sheet. Periodic checks are made to determine when corrosion products first develop. If necessary, the test can be accelerated by heating the stack.

Chemical tests

A typical chemical test that can be used to check corrosion resistance is a spot test in which a chemical solution is allowed to dissolve the chromate coating and react with and color the base metal. The degree of corrosion protection is established empirically by the time to produce a reaction and the extent of the reaction.

A measure of corrosion resistance can also be obtained by analyzing the amount of hexavalent chromium present after the conversion coating has been removed. However, this test only works under certain conditions, as it does not differentiate between soluble and insoluble hexavalent chromium. Consequently, it cannot detect whether the coating has been dehydrated as a result of overheating.



1—Several types of precision wire wound resistors. Among the devices that requires such resistors are potentiometers, resistance boxes and bridges, and voltmeter and wattmeter multipliers.

When You Need Alloys for Precision Resistors . . .

*. . . here are the important factors to consider and how some of the best known alloys compare with each other**

by C. M. Jackson and J. G. Dunleavy, *Battelle Memorial Institute*

■ There are several hundred alloys specifically designed for precision electrical resistors. This article should help you pick the right one to perform a given function.

TABLE 1—MODIFIED NICKEL-CHROMIUM ALLOYS (HIGH RESISTIVITY)

Type	Tradename	Manufacturer	Nominal Electrical Resistivity (20 C)		Nominal Temperature Coefficient of Electrical Resistance[a]	
			Ohms per Circular Mil Foot	Microhm[b] Centimeters	Parts per Million per °C	Temperature Range, C
Ni-Cr-Al-Fe	Karma	Driver-Harris Co.	800	133	±10	20 to 105
Ni-Cr-Al-Cu	Evanohm	Wilbur B. Driver Co.	800	133	±10	−65 to +125
Ni-Cr-Mn-Mo	Jelliff Alloy 800	C. O. Jelliff Mfg. Corp.	800	133	±10	25 to 100
Ni-Cr-Si-Mn	Nikrothal L	Kanthal Corp.	800	133	±10	−65 to +150
Ni-Cr-+ Additions	Moleculoy	Molecu-Wire Corp.	800	133	±10	−65 to +125
Ni-Cr-Fe	Nichrome	Driver-Harris Co.	675	112	+150	20 to 100
Ni-Cr-Fe	Tophet C	Wilbur B. Driver Co.	675	112	+130	20 to 500
Ni-Cr-Fe	Chromel-C	Hoskins Mfg. Co.	675	112	+169	20 to 500
Ni-Cr-Fe	Jelliff Alloy C	C. O. Jelliff Mfg. Corp.	675	112	+150	25 to 100
Ni-Cr-Fe	Nikrothal 6	Kanthal Corp.	675	112	+140	−65 to +250
Ni-Cr-Fe	Electroloy	Molecu-Wire Corp.	675	112	+130	−65 to +250
Ni-Cr-Fe	Chromic C	Riverside-Alloy Metal Div., H. K. Porter Co.	675	112	+170	20 to 100
Ni-Cr-Fe	Techalloy 62-15	Techalloy Co., Inc.	675	112	+130	0 to 100

[a]The reported coefficients frequently hold for broader temperature ranges than those given.
[b]1 microhm-centimeter = 6.015 ohms per circular mil foot.

An electrical resistor is a device which provides a specified resistance in an electrical circuit. A precision fixed resistor (see Fig 1), designed to operate at one specified resistance value, is defined as one with an electrical resistance tolerance of 1% or less. The resistance must initially be within 1% of the nominal value and must remain within that range for long periods of time. Some precision resistors have tolerances as low as 0.01%, and laboratory "standard" precision resistors have even lower tolerances.

Precision fixed resistors are commercially produced as film or wire-wound types. This article is concerned with the latter type.

Three important characteristics of resistor alloys

Electrical resistivity — This is an important property since it determines electrical resistance of a given length of wire. Electrical resistivity is directly proportional to the length of the wire (l) and the electrical resistivity of the alloy (ρ) and inversely proportional to the cross-sectional area of the wire (A). Thus, $R = \rho l/A$

Higher resistance is obtained by increasing ρ or l or decreasing A. Since most of the alloys are available in diameters down to 0.0005 in., the extent to which A may be decreased is limited by this minimum size.

Temperature coefficient of electrical resistance — This property specifies change in resistance of an alloy with temperature. For precision resistors to stay within

* In addition to the companies named in this article some 25 other reputable manufacturers produce resistor alloys.

their tolerances of 1% or less, the alloys must have a low coefficient. The coefficient is usually expressed in parts per million per °C (0.0001% per °C) for the stated temperature range.

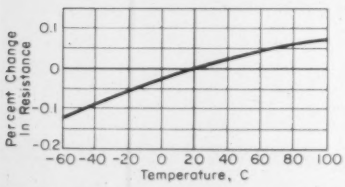
Fig 2 gives the percent change in resistance versus temperature for one resistance alloy. If the slope of this type of curve is linear, then the coefficient is the same over the entire temperature range. If it deviates from linearity, the temperature coefficient itself varies with temperature. The latter case is the one usually found.

Stability—The ability of resistor alloys to operate for long periods of time at specified temperatures and in certain environments with little or no change in total resistance is important. To improve their stability, precision wire-wound resistors are usually heat-treated after winding to minimize structural changes in the alloy and to eliminate stresses resulting from the winding operation. The final calibration of the resistors takes place after this stabilizing heat-treatment.

Even though stabilized, a momentary overheating of the wire because of overloading during use can alter the resistance value of the resistor. This effect is particularly insidious because the resistor may not burn out or show external signs of failure although its resistance has changed significantly.

The resistor alloys

The major commercially available alloys generally used for resistor windings, their manufacturers and nominal electrical properties are listed in the accompanying tables. Properties in each case are those supplied by the manufacturer of the alloy. From these tables it can be seen that the alloys are of five general types: modified nickel-chromium,



2—*Change in resistance, as affected by temperature, for one common resistance alloy.*

How Precision Resistors Are Made

Precision wire wound resistors are made by winding a definite length of resistance wire on a suitable peg or bobbin. Total resistance is directly proportional to the length of the wire. Generally, the direction of winding is reversed several times along the length of the bobbin to reduce the inductance of the completed resistor.

If the operating temperature of the resistor varies, the bobbin material must have a coefficient of thermal expansion compatible with that of the resistance wire. Otherwise, stresses set up in the wire by the thermal expansion of the bobbin could change the resistance value of the component.

Insulation of the wire is obtained by means of a suitable enamel or other protective coating and is used to prevent short-circuiting of the winding. In addition, insulation protects the wire from atmospheric corrosion. Where more complete atmospheric protection is necessary, the winding is hermetically sealed in a casing.

TABLE 2—NICKEL-CHROMIUM ALLOYS (HIGH RESISTIVITY)

Type	Tradename	Manufacturer	Nominal Electrical Resistivity (20 C)		Nominal Temperature Coefficient of Electrical Resistance[a]	
			Ohms per Circular Mil Foot	Microhm Centimeters	Parts per Million per °C	Temperature Range, C
Ni-Cr	Nichrome V	Driver-Harris Co.	650	108	+110	20 to 500
Ni-Cr	Tophet A	Wilbur B. Driver Co.	650	108	+85	20 to 100
Ni-Cr	Chromel A	Hoskins Mfg. Co.	650	108	+123	20 to 500
Ni-Cr	Jelliff Alloy A	C. O. Jelliff Mfg. Corp.	650	108	+100	25 to 100
Ni-Cr	Nikrothal 8	Kanthal Corp.	650	108	+80	−65 to +250
Ni-Cr	Protoloy A	Molecu-Wire Corp.	650	108	+110	−65 to +250
Ni-Cr	Chromic A	Riverside-Alloy Metal Div., H. K. Porter Co.	650	108	+130	20 to 100
Ni-Cr	Techalloy 80-20	Techalloy Co., Inc.	650	108	+100	0 to 100

[a]The reported coefficients frequently hold for broader temperature ranges than those given.

TABLE 3—IRON-CHROMIUM-ALUMINUM ALLOYS (HIGH RESISTIVITY)

Type	Tradename	Manufacturer	Nominal Electrical Resistivity (20 C)		Nominal Temperature Coefficient of Electrical Resistance[a]	
			Ohms per Circular Mil Foot	Microhm Centimeters	Parts per Million per °C	Temperature Range, C
Fe-Cr-Al	Alloy 815-R	Hoskins Mfg. Co.	815	136	±10	−65 to +150
Fe-Cr-Al	Alloy K-20	C. O. Jelliff Mfg. Corp.	815	136	±20	25 to 100
Fe-Cr-Al-Co	Kanthal DR	Kanthal Corp.	812	135	[b]	−50 to +150
Fe-Cr-Al	Carpenter 1-JR	Carpenter Steel Co.	720	120	+100	20 to 100

[a]The reported coefficients frequently hold for broader temperature ranges than those given.
[b]Manufacturer specifies a nominal temperature coefficient of ±5 ppm from a "standard temperature coefficient curve." The "standard curve" has a temperature coefficient of −7.5 ppm at −50 C and +7.5 ppm at +150 C.

nickel-chromium, iron-chromium-aluminum, copper base and noble metal alloys.

For high resistance—Because of their high electrical resistivities, the modified nickel-chromium (Table 1), nickel-chromium (Table 2), and iron-chromium-aluminum alloys (Table 3), are usually selected for high-ohmage precision resistors. Final choice of the particular alloy for a specific resistor application depends primarily on the temperature coefficient of resistance required. The temperature coefficients of these alloys normally vary from about 10 ppm per °C to about 150 ppm per °C from 20 to 100 C. However, some of the alloys may be purchased on special order with temperature coefficients very close to 0 ppm per °C from 20 to 100 C.

For relatively low resistance—The copper base electrical resistance alloys, such as the copper-nickel and copper-manganese-nickel types listed in Table 4, are of relatively low resistivity (about 300 ohms/cmf). Consequently, these alloys are used primarily in precision resistors for low-ohmage applications.

For corrosion service—The noble metal (precious metal) resistance alloys listed in Table 5 are used primarily as resistance windings in potentiometers — principally because of their inherent resistance to atmospheric corrosion. The absence of a corroded surface layer on the wires permits the use of low contact pressures in potentiometers wound with noble-metal resistance alloys.

TABLE 4—COPPER-BASE ALLOYS (LOW RESISTIVITY)

Type	Tradename	Manufacturer	Nominal Electrical Resistivity (20 C)		Nominal Temperature Coefficient of Electrical Resistance*	
			Ohms per Circular Mil Foot	Microhm Centimeters	Parts per Million per °C	Temperature Range, C
Cu-Ni	Advance	Driver-Harris Co.	294	49	±20	20 to 100
Cu-Ni	Cupron	Wilbur B. Driver Co.	294	49	±20	20 to 100
Cu-Ni	Copel	Hoskins Mfg. Co.	294	49	±20	−65 to +150
Cu-Ni	Jelliff Alloy 45	C. O. Jelliff Mfg. Corp.	294	49	±20	25 to 100
Cu-Ni	Cuprothal	Kanthal Corp.	294	49	±20	20 to 100
Cu-Ni	Neutroloy	Molecu-Wire Corp.	300	50	±20	−65 to +250
Cu-Ni	Excelsior	Riverside-Alloy Metal Div., H. K. Porter Co.	294	49	±20	20 to 100
Cu-Ni	Techalloy 45-55	Techalloy Co., Inc.	294	49	±20	0 to 100
Cu-Mn-Ni	Manganin	Driver-Harris Co.	290	48.2	±15	15 to 35
Cu-Mn	Manganin	Wilbur B. Driver Co.	290	48.2	±15	15 to 35

*The reported coefficients frequently hold for broader temperature ranges than those given.

TABLE 5—NOBLE-METAL ELECTRICAL RESISTANCE ALLOYS (WHEN CORROSION RESISTANCE IS IMPORTANT)

Type	Tradename	Manufacturer	Nominal Electrical Resistivity (20 C)		Nominal Temperature Coefficient of Electrical Resistance	
			Ohms per Circular Mil Foot	Microhm Centimeters	Parts per Million per °C	Temperature Range, C
Au-Pd-Fe	Alloy 1729	Baker Platinum Div., Englehard Industries, Inc.	1100	183	−280	0 to 100
Pd-Au-Fe	Alloy 1780	Baker Platinum Div., Engelhard Industries, Inc.	950	158	<10	0 to 100
Pd-Mo	Alloy 486	Secon Metals Corp.	610	102	+55	0 to 100
Au-Ni-Cr	L. T. C.	Sigmund Cohn Corp.	550	92	+20	0 to 100
Pt-Rh	Alloy 449	Secon Metals Corp.	545	91	+45	0 to 100
Pd-Mo	Alloy 445	Secon Metals Corp.	500	83	+90	0 to 100
Pd-Mo	Alloy 430	Secon Metals Corp.	465	77	+200	0 to 100
Pt-W	Alloy 1765	Baker Platinum Div., Engelhard Industries, Inc.	400	67	+230	0 to 100
Pt-W-Mo	Alloy 436-D	Secon Metals Corp.	400	67	+210	0 to 100
Pt-W	Alloy 479	Sigmund Cohn Corp.	400	67	+240	0 to 100
Pd-Ag	Alloy 464	Secon Metals Corp.	230	38	+50	0 to 100
Pd-Pt-Au-Ag-Cu	Paliney 7	J. M. Ney Co.	200	33	+300	0 to 100
Pd-Pt-Au-Ag-Cu	Fremaloy 301	Handy & Harmon	200	33	+300	0 to 100

New alloys are needed

Most alloys for use in precision resistors maintain their precise electrical resistivity and temperature coefficient characteristics to temperatures of about 300 C (570 F). Above these temperatures, however, most of the alloys undergo complex metallurgical changes which affect their electrical properties and, consequently, the stability of the alloys and the resistor.

These limitations are becoming increasingly restrictive. This is particularly evident in military applications, where precision resistors are needed with high stability and very low temperature coefficients of resistance at operating temperatures of 500 C (930 F) and above. The instability and relatively high temperature coefficients of the presently available electrical resistance alloys at these temperatures will necessitate the development of new alloys to meet these needs.

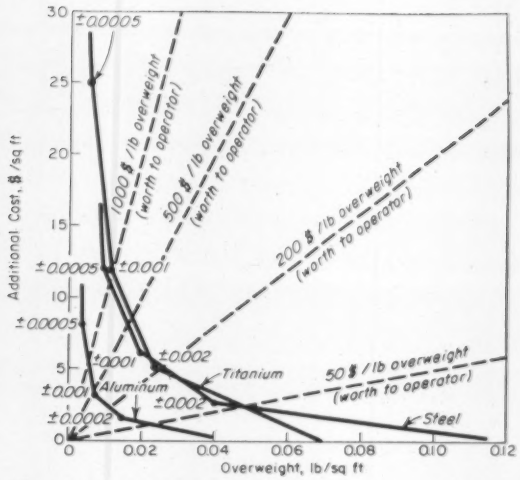
Acknowledgments

The authors wish to thank the companies listed in this article for information supplied. We are also grateful to A. M. Hall and Orval L. Linebrink of Battelle Memorial Institute for their critical review and helpful comments.

If you can estimate the dollar value of each pound of weight saved in your product, this article will show you

How to Specify Optimum Tolerances for Sheet

by **George A. Hoffman,** *Rand Corp.*



1 ***Use this graph*** *to determine optimum sheet tolerances where weight savings are important. See text below for discussion.*

■ The graph above (Fig 1) makes it possible to choose the economically optimum sheet tolerance for sheets of aluminum, steel or titanium. The method of establishing this plot will be discussed later in this article.

In reading this final graph, it is not necessary to consider values of the abcissa or ordinate. For example, if it has been estimated, for a particular case, that savings in overweight are worth from \$200 to \$500 per lb, the tolerances may be read from the broken-line curves that lie in this portion of the graph. Aluminum and steel sheet tolerances are economically optimum at ±0.001 in. Titanium optimum tolerances lie between ±0.0015 and ±0.002 in. These values, like all graphs and calculations in the article, are based on a sheet size of 36 × 96 in., 0.063 in. thick. Similar graphs can be plotted for other sheet sizes.

How to estimate worth of overweight savings

To use a graph like Fig 1 you have to be able to estimate the dollar savings of each pound of weight saved. Methods of determining such an estimate are, of course, entirely dependent upon particular products and industries. The aircraft industry will be used as an example here, but even within this industry, there is a great range of opinion. A list of some estimates made by responsible personnel indicates the width of these divergent opinions:

1. British prop-jet transport, \$98/lb.
2. British fighter-interceptor, \$220/lb.
3. British jet transport, \$560-840/lb.
4. American jet transport, \$600-800/lb.
5. American commercial piston-engine transport, \$2065/lb.
6. Explorer IV, \$15,000/lb.
7. Explorer I, \$30,000/lb.

For this reason, "rays" have been plotted on the graph to represent various cost savings ranging from \$50 to \$1000 per lb. It can be seen that, despite the broad range in dollar savings, there is only a narrow spread in the economically optimum tolerances.

The box on the next page contains an example of the factors involved in calculating figures like those listed above.

Structural weight reductions of the order discussed in this article are worthy of attention. This is particularly true because they can be accomplished with no change in structural manufacturing practice. They are achieved by rearranging purchasing practices and convincing the user of the product of the advantages of such additional expenditures.

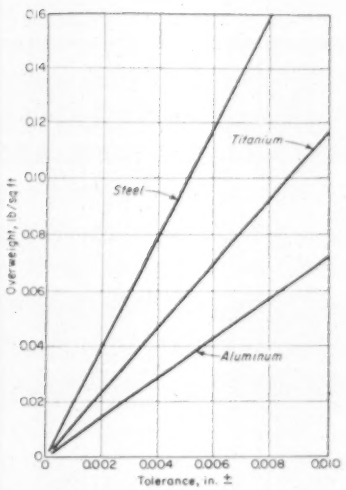
Production level affects cost of tighter tolerances

In arriving at the graph of Fig 1, it was necessary to consider the additional cost involved in obtaining sheet with tighter tolerances. This additional cost is taken into account in the graph, as will be shown later. However, such costs are dependent upon production

OPTIMUM TOLERANCES BASED ON THICKNESS AND PRODUCTION LEVEL

Sheet Thickness, in.	Beryllium Tolerance, in.[a]		Titanium Tolerance, in.[a]		Aluminum Tolerance, in.[b]		Steel Tolerance, in.[b]	
	10,000 Lb/Yr	50,000 Lb/Yr	10,000 Lb/Yr	100,000 Lb/Yr	Optimum	Commercial	Optimum	Commercial
0.002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	—
0.020	0.0015	0.0012	0.0015	0.0010	0.0007	0.001	0.0008	0.002
0.063	0.0050	0.0030	0.0030	0.0020	0.0020	0.004	0.0020	0.006
0.125	0.008	0.005	0.006	0.004	0.003	0.005	0.004	0.010
0.250	0.012	0.008	0.009	0.006	0.005	0.013	0.005	0.017

[a]Based on assumed production levels shown. [b]Based on actual production levels.



2 ***Extraneous weight*** *added by tolerance allowances is plotted simply from the density of the material and the sheet dimensions.*

levels, not only of the sheet material, but of the particular thickness involved.

The higher the production level, the cheaper it will be to attain a given tighter tolerance. This means that the economically optimum tolerance in such a case will then become a tighter tolerance. The table included here illustrates this point for beryllium and titanium by comparing optimum tolerances for two different production levels. For steel and aluminum the table compares the optimum tolerances based on present production levels to commercial tolerances. The differences indicate that the economically optimum tolerances of all sheet thicknesses of all materials may be smaller than those presently standard in the aircraft and missile industry. The conclusion to be drawn—that sheets used in flight vehicles today are overweighted by excessively loose tolerances—should be of vital concern to the industry.

Another point illustrated by the table is the tendency of incremental cost to vary with gage thickness. Because there is a growing demand for increasingly thinner gages, production in this area will rise, allowing tighter optimum tolerances. This unbalanced production will undoubtedly be necessary to meet the demands of sandwich design where face sheets will be less than half the gage of equivalent sheet-stringer designs, and thin foil will be needed for core materials. For such design, then, optimum tolerances will undoubtedly grow tighter.

Finally, the table and the graph bring out the point that cost factors actually constitute a design factor influencing structural weight, and must be considered along with the configuration of structural elements and the selections of materials. For example, an expenditure increase when purchasing titanium sheets could reduce structural weight by 3.6 to 5.3%. This figure is calculated in this manner: If design thickness is 0.056 in., commercial sheet of 0.063 ±0.006 in. would be purchased. At minor cost, a tolerance of 0.004 in. could be obtained and weight saving would be $100\% \times (0.006 - 0.004)/0.056 = 3.6\%$. At somewhat higher cost, a tolerance of 0.003 in. could be obtained with resultant weight saving of $100\% \times (0.006 - 0.003)/0.056 = 5.3\%$.

How the optimum tolerance graph is derived

As in many industries, specifying sheet tolerances for aircraft requires a balance between two facts: 1) liberal tolerances reduce purchasing cost and speed delivery, and 2) tight tolerances raise costs but reduce extraneous weight and may thus save money in operation. The graph of Fig 1 was derived by plotting both extraneous weight (Fig 2) and additional cost (Fig 3) as functions of the tolerance, then combining the graphs to obtain a plot of additional cost vs overweight (Fig 4).

Extraneous weight (Fig 2). The extraneous material (i.e., the material beyond the thickness required by the design) in a manufactured sheet results from two types of deviation from the "perfectly" dimensioned flat sheet:

1. Variation in the thickness of the sheet along the rolling direc-

Specific Examples of the Value of Weight Saving

Consider the aluminum structure of a modern jet transport aircraft. According to the table, tolerances between ±0.0020 and ±0.007 in. should be specified, at additional costs up to $2 per sq ft of surface. This cost may seem high, but there are more than 10,000 sq ft of sheet and plate in such a transport, with a weighted commercial (average) tolerance of ±0.006 in. Reduction to, say, ±0.0015 would save 650 lb. There are two ways in which a dollar value might be assigned to this 650 lb.

1. *Passenger capacity can be increased* (in one particular model) from 88 to 90 by simply installing 2 more seats in the already designed transport. The worth to the operator has increased from the initial cost of $4,500,000 to (90/88) × $4,500,000 = $4,600,000, if operation at full capacity is assumed.

The $100,000 increment in value, divided by the 10,000 sq ft, gives a worth of $10 per sq ft. This is well above the $2 per sq-ft originally paid to increase the value. The worth of a pound saved in this instance is $100,000/650 lb, or about $154 per lb.

2. *Reduction in operating cost* can be accomplished in an aircraft made of very-close-tolerance sheets and plates. Assume that the 650-lb weight saving is used by the operator only to reduce fuel-consumption expenditures. Over the 12-year (or 43,800 hr) life of the transport, fuel cost savings can be calculated thus:

Thrust required = 650 lb/18 (lift:drag) = 36.1 lb. Fuel required is 1.2 lb per lb thrust or 43.32 lb fuel/hr. For the total time:

Fuel required = 43.32 lb fuel/hr × 43.800 hr = 1,897,416 lb

Fuel cost per lb = ($0.15/gal)/(6.5 lb/gal) = $0.0231/lb

Total cost = 1,897,416 lb × $0.023/lb = $44,000.

The $44,000 gives a value to the tightened tolerances of $4.4/sq ft, and the worth of a pound of weight saved is $68.

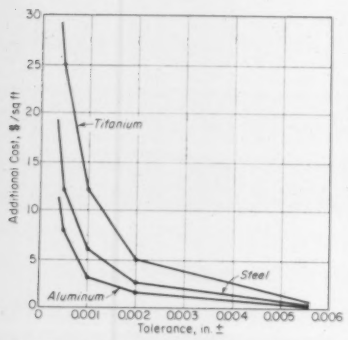
tion. This variation is experienced from sheet to sheet and also, to a lesser extent, within a sheet. Its occurrence is due to variations in the material properties at the rolling temperature, and to imperfections of the rolling machines.

2. Variation in the thickness of the sheet perpendicular to the rolling direction. Sometimes this variation results in thin edges and a high center, called a "crown." It is directly attributable to the design of the rolling mill. Lately, improved sheet fabricating methods have eliminated much of the crown, although random variations may occur across the width of the sheet which are comparable to those along the rolling direction.

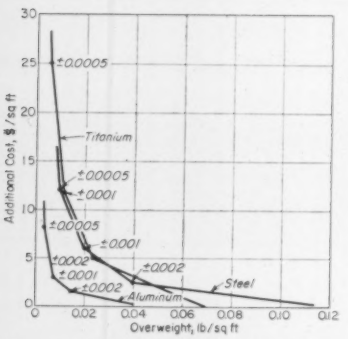
The additional overweight resulting from using standard stock gages instead of the design-required thickness is not considered here, although it may represent a penalty as high as 7% of primary structural weight. Also not considered here is the weight penalty paid when using small sheets because wider and longer sheets are not available.

Overweight per square foot of sheet can be obtained from the formula: $(0.5)^2 \times$ (total magnitude of tolerance, in.) $\times$ (144 sq. in./sq ft) $\times$ (density, lb/cu in.).

The 0.5 is a factor that accounts for the randomness of gages within the permissible tolerance of sheets actually used in fabrication. The factor is squared to account for randomness parallel and perpendicular to the rolling direction. The densities used in this article are: 0.067 lb per cu in. for beryllium, 0.101 for aluminum (7178), 0.162 for titanium (6Al-4V), and 0.276 for steel (17-7 PH).



3 Additional cost *of obtaining various tolerances is plotted against the overweight added by the tolerance.*



4 Intermediate graph, *plotted by combining Fig 2 and 3, makes it possible to determine optimum tolerance graph shown in Fig 1.*

Additional cost (Fig 3). Deviations from the required thickness of sheet can be held to a minimum by a number of methods. A few of these are discussed here in order of successively higher cost increments over commercial tolerance sheets.

The cost increments will be calculated for 0.063 $\times$ 36 $\times$ 96-in. titanium sheet. Costs are purposefully estimated on the high side and in 1959 dollars. They are to be interpreted only as an illustration of the method.

1. Conduct an "all-over" inspection of sheets rolled to commercial tolerances (±0.006 for 0.063 gage); retain half of the sheets with the best tolerances; reprocess the remaining half. This procedure finds a precedent in the large-scale scrapping, for special reasons, in aircraft production involving aluminum and titanium. The best-dimensioned half of the sheets will have a closer tolerance, e.g., ± 0.002 for 0.063-gage sheet.

Cost of reprocessing the remaining sheets (in $ per sq ft) can be calculated as:

Reprocessing cost per lb = 8.5–4.0 = $4.5/lb, where: $8.5/lb = cost of rolled sheet; $4.5/lb = reuse value of discarded half of sheets.

Reprocessing cost per sq ft = $4.5/lb $\times$ 0.063 in. $\times$ 144 sq. in./sq ft $\times$ 0.162 lb/cu in. = $6.5/sq ft.

The cost of inspection and handling was assumed to be negligible in comparison with the figure of $6.5 per sq ft.

2. Roll sheets in special high precision mills specifically designed to produce very accurate thicknesses. Such mills might yield 0.063-gage sheets with ± 0.001 tolerance. Such a mill, estimated to cost $6,000,000, and to have a life of 12 years, might be in use only half the time for titanium. Then:

Maintenance = ($6,000,000 $\times$ 1.2 maintenance factor)/12 years = $600,000/yr

Operating cost = $100,000/yr (assumed)

Total annual cost chargeable to titanium = ½ ($600,000 + $100,000) = $350,000

Assuming 30,000 lb is the weight of titanium sheet that might be rolled in a peak year, the incremental cost will be on the order of:

($350,000 $\times$ 1.47 lb/sq ft/30,000 lb = **$17/sq ft.**

This cost of $17 is high compared to the prospects of finish-grinding to ±0.001 the as-delivered sheets. There are indications from present experiments that production grinding to such accuracy is feasible and might tentatively cost about $12 per sq ft for 0.063-in. sheet titanium.

3. Skin-grind sheets down to ± 0.0005 in. in special mills (still in the design stage). Polishing mills capable of ±0.0005 production accuracy on titanium are yet to be designed: only tentative estimates have been made that the cost of achieving ± 0.0005 may be double that of obtaining ± 0.001.

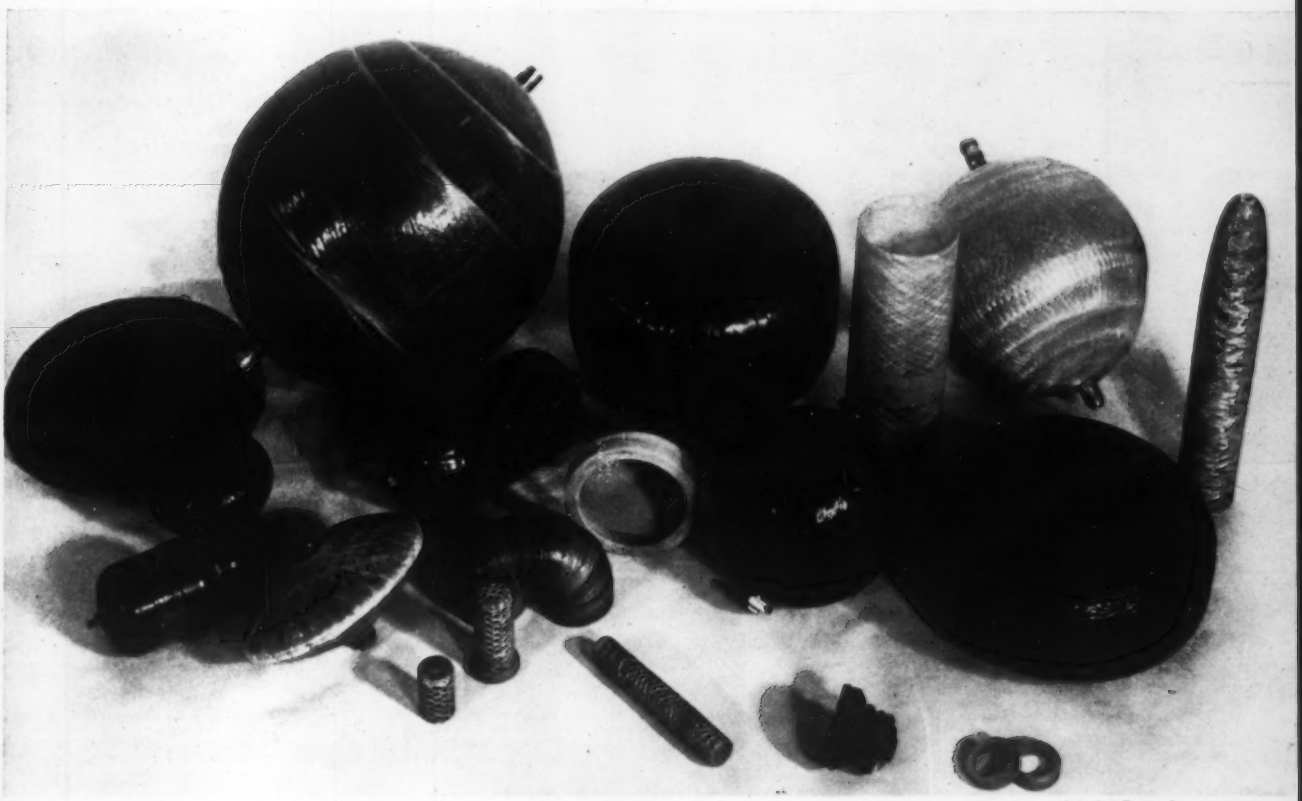
Additional cost vs extraneous weight (Fig 4). The graphs of Fig 2 and Fig 3 can now be combined to obtain a plot of additional cost vs the overweight. This graph is most convenient to use because the worth to the customer in savings on overweight can be plotted directly as "rays" whose slope is a measure of dollars saved per lb overweight. Thus the final graph of Fig 1 is determined, making it possible to estimate the optimum tolerance.

More Engineering & Design on page 208

A SPECIAL 3-PART REPORT ON

Filament Wound Reinforced Plastics: State of the Art

M/DE Special Report No. **174**—*August, 1960*



Aerojet-General

Variety of parts *made by filament winding indicates design potential of the process for maximum strength-weight.*

1.

What you can expect from the parts

A reporter's broad look at the design data available, reinforcements and resin systems, and process modifications and variations.

by Malcolm W. Riley
Associate Editor, Materials in Design Engineering

2.

How to evaluate the materials

Here is one company's formalized testing procedure for materials selection and evaluation, and a discussion of specialized test methods.

by J. H. Lieb and E. H. Jaffe
Materials Engineering, Rocketdyne, Div. of North American Aviation, Inc.

3.

How process variables affect performance

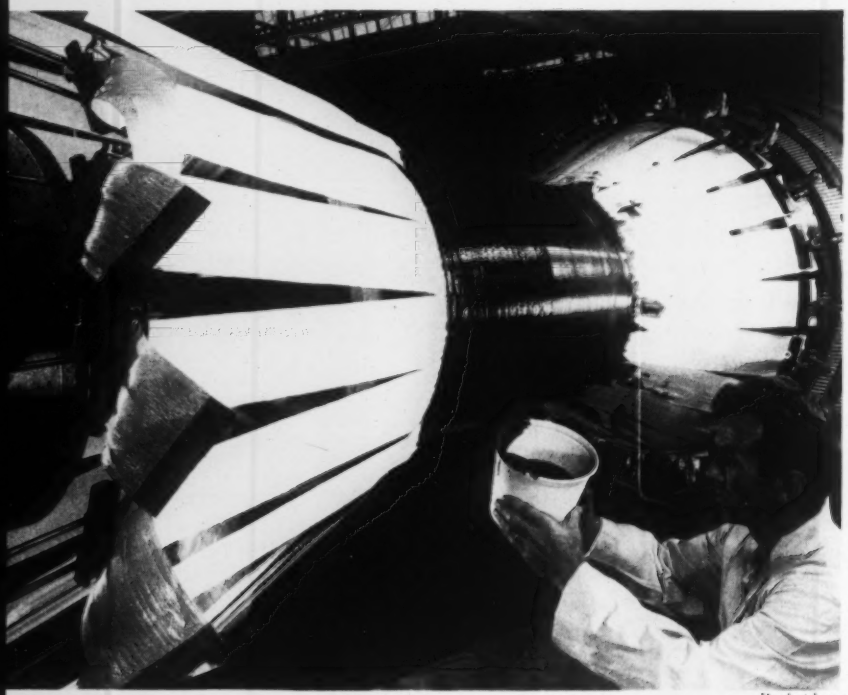
The first report on a study of the effects of materials and process variables on end properties of filament wound structures.

by S. A. Miller and J. S. Carter
R&D Engineering, Brunswick Corp.

PART 1

What You Can Expect from Filament Wound Parts

by **Malcolm W. Riley,** *Associate Editor, Materials in Design Engineering*



Rocketdyne

***One technique** of applying longitudinal reinforcements when circumferential winding is shown in this photo of wet winding.*

■ Tailor-make an engineering material as the structure is produced: this concept is the basis for filament winding reinforced plastics. It is responsible for the outstanding benefits of the process—and also the problems in designing and specifying the material and the structure.

On one hand filament winding produces a part of maximum structural efficiency by putting the strength where you need it. On the other hand, success of the structure is highly dependent on 1) accurate initial stress analysis of the part, 2) careful planning and control of the production process, and 3) development of accurate and meaningful methods for evaluating the performance capabilities of a complex, composite material.

The raw materials are high strength-weight continuous filaments and a resin binder—usually conventional E glass and epoxy resins. The winding process applies the filaments and resin to a turning mandrel in any of a variety of winding patterns designed to orient the filaments so that in service they are stressed as purely in tension as possible. The resin serves to distribute the load among the filaments (to preclude sequential breaking of filaments), and to protect the filaments from both degrading environments and interfiber abrasion.

In terms of its commercial potential filament winding is a new process and much more an art than a science. The first section of this special three-part report is intended to summarize as clearly as possible 1) what you can expect to get in a filament wound part, 2) present status and future developments in terms of reinforcements and resin systems, and 3) some of the more important process variables affecting final performance of the structure.

Pros and cons of filament winding

Unidirectional strength-weight ratios of 2-2.5 million inches are commonly quoted for filament wound structures. This high ratio is primarily due to 1) the high strength-weight ratio of the glass filament (e.g., although single fiber strength values as high as 400,000 psi have been reported, more commonly encountered values are about 200,000-250,000 psi ultimate tensile strength divided by 0.092 lb per cu in. density), and 2) the fact that such structures have the highest glass content (80-90% by weight) of all reinforced plastics materials.

Many glass-reinforced plastics structures are stronger on a unit-weight basis than metals. But putting the reinforced composite together in such a way that the primary load-bearing members (i.e., the glass filaments) are used to maximum efficiency in the final structure is the aim of the filament winding technique.

Maximum efficiency

The fact that the individual filaments are primarily loaded only unidirectionally in tension makes it possible to design structures of maximum efficiency. For example, in

cylindrical pressure vessels, the ratio of hoop stress to longitudinal stress acting in the wall is 2:1.

In metal pressure vessel design, the benefit of the sphere over the cylinder is that the same stress is present in both directions. In designing cylinders in metal, although the longitudinal stress is only one-half the hoop stress, the wall thickness must be designed to withstand the hoop stress. Consequently, since metals are essentially isotropic in strength, the product of operating pressure and volume capacity (PV) per unit weight of material is less in the cylinder than in the sphere for a given peak stress.

In filament wound cylinders, however, the reinforcement is so oriented and proportioned that the hoop strength of the cylinder wall is actually twice the longitudinal strength. Consequently, the PV per unit weight of material is the same in the cylinder as it is in the sphere for a given peak stress. Conversely, at a given fiber stress, the filament wound cylinder has the same weight for a given pressure and volume as a filament wound sphere.

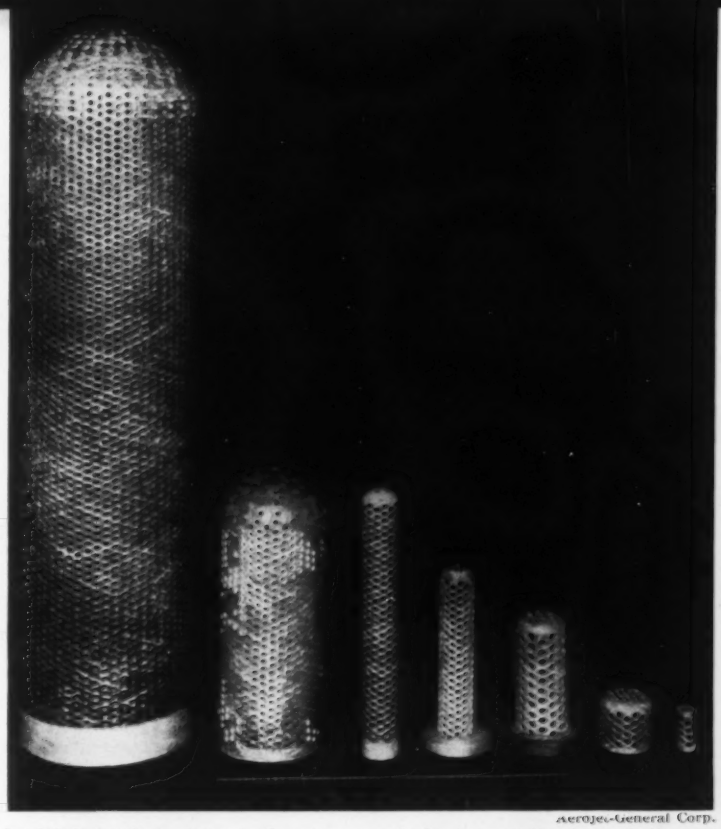
This unique constancy of weight-per-unit-volume relationship, independent of size and shape, has obvious pertinence to the design of solid-fuel missile propulsion systems. It provides a unique freedom of design in terms of shape, size and number of motor cases in a given propulsion system.

Other benefits

Other benefits of filament wound reinforced plastics stem from the mechanized nature of the process which results in 1) ability to closely control process variables, resulting in uniformity and reproducibility of quality, 2) economical large volume production, and 3) consistent wall thickness.

Limitations

Filament wound structures have obvious limitations on shape since they are wound or wrapped on a forming mandrel. Also, parts are inherently weak in interlaminar shear. There is relatively little interlocking between layers of unidirectional reinforcement, in comparison with that which occurs between plies of cloth. However, the degree of interlocking depends to some extent on the type of winding used (e.g., helical winding can be controlled to give a relatively high degree of interlocking at some sacrifice in hoop strength).



Aerojet-General Corp.

Ignition baskets *for missiles are one of the few applications of filament winding that make use of conventional styrene-polyester resins. Note the complex wound-in holes.*

The higher strength and rigidity of filament wound structures result in a sacrifice in ductility. This in turn reduces certain other properties, e.g., ultimate bearing strength which depends on ductility of the material to absorb and distribute stress concentrations and contact-stresses around a hole. Also, since the strength of the material is highly dependent on the continuous nature of the filament, there are limitations on the location and degree of cutting, drilling or grooving allowable.

Permeability of filament wound structures can be an important problem. Elastomeric liners are usually used to seal pressure vessels. The problem of providing proper liners is a subject in itself and, due to space limitations, will not be discussed here.

Probably the most important limitation for specifiers today is the empirical nature of filament winding. Although many highly successful parts have been fabricated and used, there are virtually no specific design data generally available. Most available strength data only indicate general orders of magnitude obtainable, and cannot usually be related directly to a specific structure.

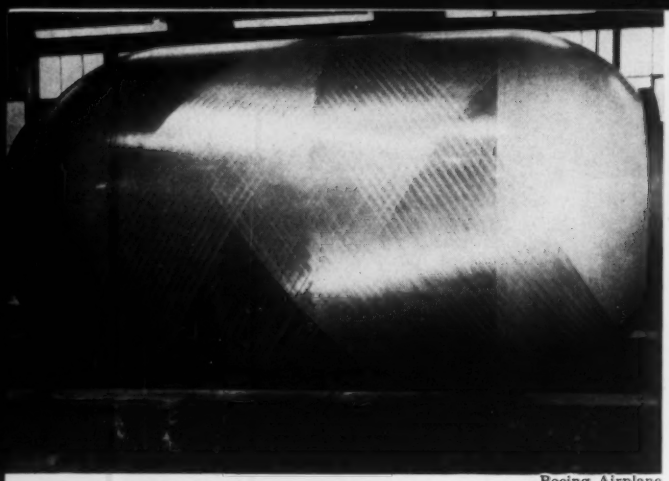
Design know-how today

Here are a few basic design principles that should be considered:

1. *Design initially for filament winding.* Do not substitute filament wound material in an original metal design. The two materials are quite different.

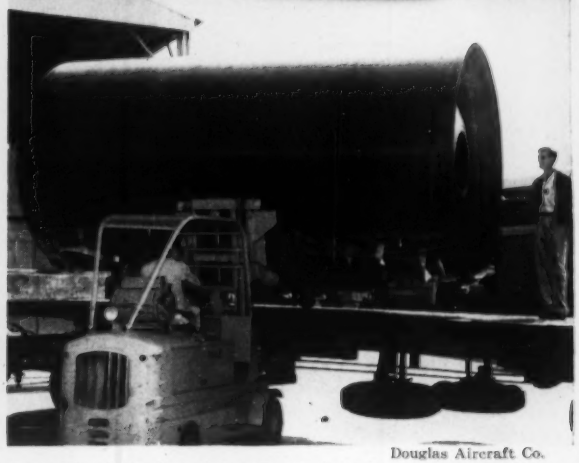
2. *Use a shape that can be wound under tension.* Reverse curvatures are extremely difficult to wind. Certain types can be produced by specialized techniques, but strength characteristics will not be optimum. Parts consisting of surfaces of revolution are ideal for winding.

Remember, too, that the part is wound on a mandrel whose exterior represents the interior configuration



Boeing Airplane

Development tank *6 ft in dia is produced by combination of helical and circ and longo winding. Incorporation of end closures is a major design problem.*



Douglas Aircraft Co.

Propellant tank *8 ft in dia, 17 ft in length and weighing 950 lb, is among the largest primary structures ever produced by filament winding. Production of shapes in such sizes is an art rather than a science.*

of the part. The mandrel must be removed after the part is formed and cured. Although special types of collapsible and soluble mandrels can be used where necessary, such techniques invariably increase the cost of the part.

3. *Close tolerances can be held with filament winding.* Wall thickness can be controlled to ±0.001 in. and closer by subsequent machining (although in some cases machining may reduce strength and environmental resistance). On overall dimensions, tolerances can be held to ±0.005 in. Of course, the closer the tolerances required, the higher the cost.

4. *Cost per part can be extremely low.* Initial investment in filament winding equipment can be relatively large. But the process can be highly mechanized, and roving used for winding is one of the least expensive forms of glass reinforcement (i.e., about 50¢ per lb for conventional roving; guaranteed end-count roving used for highest quality military components is slightly higher in cost). Consequently, for large volume production, per-part cost can be quite low.

In many cases, of course, although volume is relatively small, the performance benefits substantially offset the high cost.

Standard pressure vessels

The concensus of experts in filament winding appears to be that, with our present technology, spherical or simple tubular shapes of glass-reinforced epoxy resins in diameters up to about 8-10 in. can be accurately designed and produced with a high degree of reliability.

Spherical pressure vessels, produced by circumpolar (or "great circle") winding in these sizes are well developed, and are available as "off-the-shelf" items. Structural design of such vessels is comparatively simple, as each of the filaments essentially describes a "perfect" hoop around the sphere which, in service, is internally pressurized. Full details are given by *Wiltshire.*

Briefly, for epoxy pressure vessels, allowable design stress is calculated from the original modest 145,000 psi tensile strength of unidirectionally reinforced epoxy "fish-pole" stock. The multidirectional nature of the reinforcement in the final sphere dictates the use of an ultimate tensile hoop stress of one-half the unidirectional strength, or about 70,000 psi.

Since most pressure vessels are cycled in service, the effects of cyclic fatigue on the resin system must be taken into consideration.

S-N curves plotted from fatigue tests show the percentages by which shear strength of the epoxy system is reduced at various numbers of cycles. Using the anticipated number of cycles of the particular vessel, then, the original 70,000 psi hoop strength is reduced by the appropriate percentage to give the allowable design stress. Similarly, the minimum bursting pressure to be used in calculating wall thickness is established by working from the desired operating pressure and applying a safety factor derived from the magnitude of the effect of fatigue on strength of the material.

Standard filament wound spherical vessels are available designed for 3000 psi operating pressure over a service life of 10,000 or 1,000,000 cycles (from zero to full operating pressure and back to zero). These bottles have 5000 psi proof pressure and 7500 psi bursting strength. Bottles with burst strengths as high as 10,000 psi have been produced.

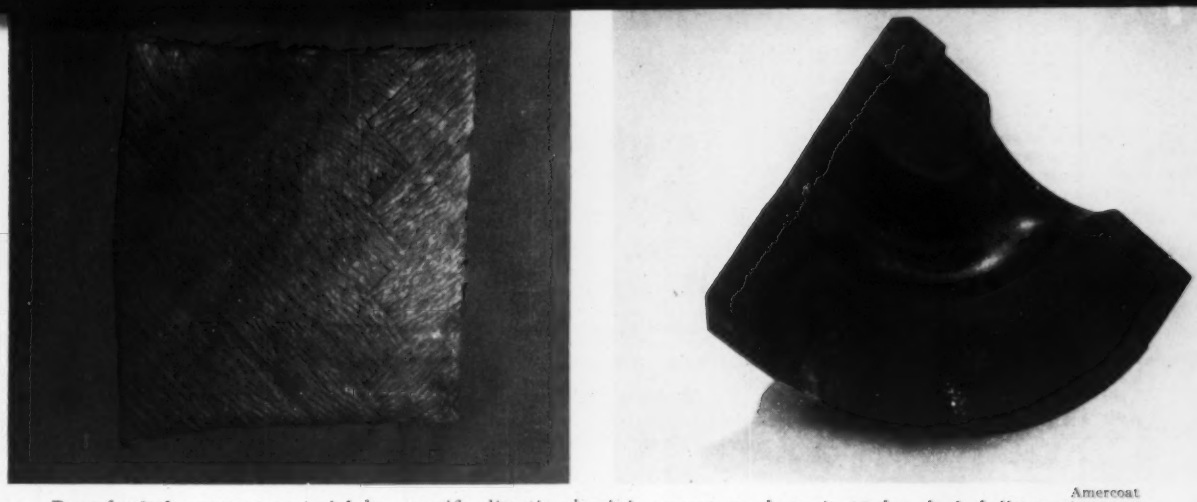
Commercial pipe produced by helical filament winding is available in i.d.'s up to about 8-10 in. Because of the helical construction, hoop stress values are about 80,000 psi, longitudinal strengths about 40,000 psi. For example, two-inch pipe for working pressures of 550 psi over a temperature range of 32-140 F is available.

A promising material: preoriented prepreg

In larger sizes and different shapes design is an art, and most of the work must be termed developmental. Most of the highly successful applications for larger and different-shaped structures (two of which are shown in the photos at the top of this page) have been developed on a trial-and-error basis.

An extremely interesting material, from the design engineer's standpoint, is a filament oriented prepreg material. The purpose of the material is to combine the preorientation of filament inherent in filament winding with the shape flexibility inherent in molding flat prepreg reinforced plastics.

Developed by Hercules Powder Co. and licensed to Amercoat Corp. and Black-Sivalls and Bryson, Inc., the material is made by winding impregnated glass roving on a cylindrical mandrel in a predetermined helix. The cylindrical structure thus produced is then slit axially, flattened and molded, or the resin can be B-staged. The material can be molded by bag or matched metal techniques.



Amercoat

Preoriented prepreg *material has specific directional reinforcement, as shown in 45 deg single helix specimen at left; conformability of the material is shown by the complex epoxy tool at right, produced by bag molding. "Wash" of fibers permits the material to conform to complex shapes.*

Winding with a 45-deg helix results in a prepreg with fibers oriented at 90 deg to each other. Different helix angles can be used to provide various degrees of directionality in strength. The material is somewhat similar to Minnesota Mining & Mfg. Co.'s Scotchply. However, in the filament wound prepreg there is a degree of "over and under" interweaving between plies to form a very loose basket-type structure. The resulting structure permits a substantial amount of "wash" of fibers in deep draw molding, allowing the material to conform smoothly to deep hemispherical draws and compound curvatures. The photo at top right indicates the conformability of the material.

Yet even with this moldability exceptionally high strength and rigidity are obtained because of the directionality of the filaments. For example, on 30-deg helix laminates (fibers oriented at 120 deg to each other) with an 80-20 glass-epoxy ratio, vacuum-bag molded specimens tested parallel to fiber orientation have flexural strengths of 100,000 psi, flexural moduli of about 3,700,000 psi, and compressive strengths of about 59,000 psi. When tested at 60 deg to fiber orientation, flexural strength is about 36,000 psi, flexural modulus is 2,600,000 psi, and ultimate compressive strength about 25,000 psi.

Press-cured silicone prepregs prepared in this manner, with 65-35 glass-resin ratio, have flexural strength in the direction parallel to fibers of 34,000 psi, and a flexural modulus of 2,300,000 psi.

Although these materials are still developmental, they appear to be highly promising for a variety of molding applications where complex shapes are encountered, yet maximum strength and rigidity are mandatory.

Property data available

Although, as mentioned before, virtually no design data are available, various types of strength data have been reported. Table 1 lists ranges of properties commonly reported by filament winders. Invariably, accompanying such data are statements to the effect that these values are only indicative of strengths obtainable under certain conditions, and many of the values appear to be highly questionable.

Unfortunately, too seldom do producers state the test methods by which these values were obtained. Possibly they feel that specifying engineers would not understand such specialized methods as the NOL Ring Test, and the modified ASTM tensile test. Or, since the data are not to be used in design, possibly they feel that giving the test method is unnecessary. Nevertheless, the data are even more meaningless without a reference to the test method used.

From the standpoint of strengths obtainable, circumferential winding of glass-epoxy systems can produce cylinders with hoop tensile strengths on the order of 180,000-200,000 psi. With a specific gravity of 2.1 (0.076 lb per cu in.) this level results in strength-weight ratios of about 2,370,000-2,640,000 in. Table 2 shows strength-weight ratios for several other materials for comparison.

Although few current designs achieve the 200,000 psi hoop strength level, 150,000-160,000 psi is fairly common. According to *Zeilberger and Lieb* special test parts (flat unidirectional laminates, described in Part 2) made at Rocketdyne have achieved room temperature hoop tensile strengths of 225,000-250,000 psi. According to F. J. Darms, work at Aerojet-General Corp. has resulted in design fiber stresses of 250,000 psi; values as high as 270,000 psi have been achieved in practice.

Helically wound pressure vessels provide ultimate hoop strengths of about 130,000 psi, and axial strengths of about 65,000 psi. Using the 130,000 psi value, hoop strength-weight

TABLE 1—TYPICAL REPORTED PROPERTIES OF FILAMENT WOUND EPOXY-GLASS*

Type of Winding →	Circumferential	Helical
Density, lb/cu in.	0.075	0.075
Ult Hoop Str, 1000 psi	180-230	120-135
Ten Mod of Elast, 10^6 psi	6-8	3.0-5.5
Flex Str, 1000 psi	280	100
Interlaminar Shear Str, 1000 psi		
Par. to Fibers	3-6	3-6
Perp to Fibers	18-20	18-20
Compr Str, 1000 psi	70	70
Ten Str-Weight Ratio, 10^6 in.	2-2.5	1.6-1.8

*Values cover range of higher values commonly reported.

TABLE 2—STRENGTH-WEIGHT RATIOS OF SOME COMMON MATERIALS
(Expressed in Inches)

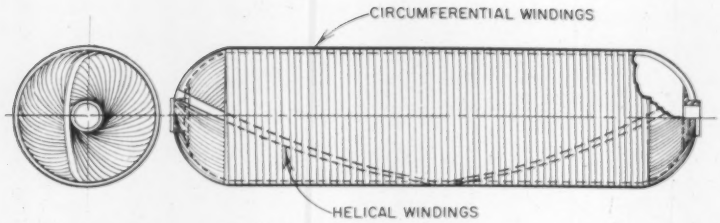
Glass-Epoxy (unidirectional)	2-2.5 x 10^6
Steels	
17-7 PH	520,000
410	490,000
4130	480,000
Aluminum	
6061-T6	350,000
7075-T6	700,000
Titanium (8% Mn)	700,000
Glass Cloth-Epoxy Laminate	740,000

Source: Adapted from *Epstein, G. and King, H. A.*

TABLE 3—PROPOSED MINIMUM PROPERTY REQUIREMENTS FOR GLASS-REINFORCED FILAMENT WOUND MATERIALS[a]

Type →	I—General Purpose	II—Heat Resistant, 300 F	III—Heat Resistant, 500 F
Sp Gr (5011 or 5012)[b]	2.0	2.0	2.0
Glass Content (7061, min), %[b]	85	85	85
Water Abs (7031, 7 day, max), wt %[b]	+0.25	+0.25	+0.25
Repetitive Loading (4.6.1.5), cycles[b]	1000	1000	1000
Stress-Rupture (4.6.1.6), hr[b]	1000	1000	1000
Ult Flex Str (1031 and 4.6.1.3, flatwise), 1000 psi[b]			
Initial	220	220	180
Wet[c]	210	210	—
At 300 F (½-hr exp)[d]	—	200	—
Flex Mod of Elast, 10^6 psi			
Initial	7.0	7.0	6.8
Wet[c]	6.8	6.8	—
At 300 F (½-hr exp)[c]	—	6.8	—
Ult Hoop Ten Str (4.6.1.1), 1000 psi			
Initial	200	200	180
Wet[c]	180	180	—
At 180 F (½-hr exp)[d]	180	—	—
At 500 F (192-hr exp)[d]	—	—	160
After Outdoor Weathering			
3 Months	180	180	—
1 Year	180	180	—
Ten Mod of Elast, 10^6 psi			
Initial	9.0	9.0	7.0
Wet[c]	8.5	8.5	—
At 180 F (½-hr exp)[d]	9	9	—
At 500 F (192-hr exp)[d]	—	—	6.0
After Outdoor Weathering			
3 Months	9.0	9.0	—
1 Year	9.0	9.0	—
Ult Axial Compr Str, (1021 and 4.6.1.2), 1000 psi			
Initial	50	50	35
Wet[c]	35	35	—
At 300 F (½-hr exp)[d]	—	35	—
Interlaminar Shear Str, 1000 psi			
Initial	10	10	7
Wet[c]	9	9	—
At 300 F	—	8	—
½-Hr Exp[d]	—	8	—
192-Hr Exp[d]	—	8	—
At 500 F (192-hr exp)[d]	—	—	6

[a]MIL-P-27327 (USAF) is a proposed specification only, developed to solicit comment from the industry; additional requirements not given here call out allowable effects of chemical fluids.
[b]Number in parenthesis refers to L-P-406 test method.
[c]Tested wet after 30-day immersion in water.
[d]Tested at temperature.



1 ***Modified ellipse,*** *or ovaloid, is used in winding in the ends of cylinders. It requires only one helix angle. Because of the low angle required, circs are wound to provide required hoop strength.*

ratios are on the order of 1,800,000 in.

Tensile modulus of elasticity generally ranges from 3 million psi for spheres to 7 million psi for cylindrical vessels. According to *Dana* of Amercoat, interlaminar shear strength of epoxy resins varies from 2000 to 5000 psi, with a realistic average of approximately 3500 psi. Filament wound cylinders designed for bending or buckling have been produced with ultimate flexural strengths approaching 100,000 psi and flexural moduli of elasticity on the order of 5-6 million psi.

Specialized attachments and closures

All pressure vessels, as well as most other devices that are filament wound, require closures of one type or another. For obvious competitive reasons, proprietary closure designs are tightly kept secrets. The most common method has been to provide a relatively large collar or flange on the base of a metal closure and wind over it, making the closure integral with the vessel.

For winding-in an integral end and closure, a modified elliptical or "ovaloid" configuration is used. Such a design not only loads the fibers properly in service, but also can be formed using only one angle of winding; a hemispherical end shape would require several winding angles. The ellipse is shown in Fig 1. Since winding-in this type of end requires a low helix angle, circumferential windings are added to provide the required hoop strength in the cylinder.

Doublers and other supporting structures can be wound into the part integrally by programming the machine to wind the doubler area at the same time the rest of the part is being wound. Young Development holds a patent on such integrally wound doublers. Doublers can be used effectively to build up end sections where a mechanically attached end closure is used.

What about specifications?

Most of the development work on filament winding has been done by proprietary organizations developing specific pieces of hardware. Consequently, there has been little correlation of results or cooperative work aimed at broadening the basic materials technology.

In an attempt to develop a broader technological base from which to work, and to establish some basic standards, the Air Force let a three-phase contract on filament winding last year. The purpose of the contract is to 1) evaluate resin systems for filament winding (Narmco Industries Inc.), 2) develop processing techniques, and study the effects of process variables on performance (subcontracted to Lamtex Industries, Inc.), and 3) evaluate and standardize test methods (subcontracted to Walter Kidde & Co., Inc.). The results of this contract should be available in early 1961.

Also, an interesting specification has been proposed by WADD (Wright Air Development Div.). Designated MIL-P-27327 (USAF) it covers glass fiber-base, filament wound plastics. It is a proposed specification only, and according to G. Peterson of WADD is admittedly unrealistic. Its prime purpose was to "stimulate comment from the filament winding industry." This it did.

The proposed specification calls out property requirements for *Type I—General Purpose; Type II—Heat Resistant, 300 F; and Type III—Heat Resistant, 500 F.* These are shown in Table 3. Although no filament winder claims at present that he can meet these minimum requirements consistently, the proposed requirements are interesting in that they point out the general nature of the specification requirements which should ultimately be developed.

Materials—present and future

Reinforcements

At present, conventional E glass in the form of roving is by far the most commonly used reinforcement in filament winding. But improvements in both type and form of reinforcement promise future property improvement, as well as increased versatility in the process.

For most filament winding, ECG 140's glass fibers are used. But rovings used by various winders differ quite substantially in end count (number of strands in a roving; each strand usually contains 204 filaments). The usual range is 8 to 20 ends, though some winders use rovings with as few as one, or as many as 60 ends.

Little evaluation work has been reported on determining the effect of end count on properties of the final part. Basically, of course, the fewer the filaments in a roving, the easier it is to stress all filaments equally. On the other hand, the longer it takes to wrap a structure.

High modulus glass—Development interest is now centered on higher modulus glass reinforcement. Several materials are now available:

1. Owens-Corning Fiberglas Corp., under Air Force contract, developed a fiber that is reported to have a modulus of about 16-18 millions psi, as compared with about 10 million psi for conventional E glass roving. The fiber is aimed at producing a laminate of 10 million psi modulus. The high modulus fiber is made of a beryllia-containing glass which poses some toxicity problems, particularly where machining is required. Although few data are available as yet the material does show promise of boosting strength-weight ratio and rigidity.

2. Another high modulus berylia glass fiber has been developed by Imperial Glass Corp. under Navy contract. Limited data are available but the fiber is said to be very similar to Owens-Corning's.

3. A unidirectional glass fiber ribbon, preimpregnated with any of a variety of resin systems, is currently available from Materials and Processes, Inc., using a high modulus glass fiber developed by Houze Glass Corp. The fiber is coated with resin as it leaves the furnace bushing, thus protecting the filament from abrasion and moisture. Houze says its fiber has single-fiber strengths 15-20% better than those of E glass. Fiber hoop stresses up to 268,000-325,000 psi and tensile moduli as high as 11 million psi have been reported. Unidirectional laminates can be designed to provide flexural strengths of 180,000-200,000 psi, and 7-9 million psi moduli. Wet strength retention is reportedly excellent (96.5% after 2-hr water boil).

Other fibers—For higher temperature applications, high silica and quartz fibers could be useful. Unfortunately, high silica fibers, such as Refrasil, have only about one-fourth the strength of E glass; quartz fibers, although somewhat stronger, are extremely expensive (e.g., $60 per lb). Actually, for long term high temperature applications, E glass is satisfactory for use with any of the resin systems developed to date. (Of possible future interest are yarns made of ceramic fibers such as those mentioned in M/DE, July '60, p 5.)

High strength metal filament (0.004-0.005-in. dia wire) reinforcement provides substantial increases in strength and modulus, as shown by the strength data and design values given in Table 4. However, strength-weight ratios are still lower than those obtainable with glass.

One of the most recent developments in metal wire for reinforcement is a 575,000-psi high carbon steel wire in diameters of about 0.004 in., produced by National Standard Co. Although this strength level improves strength-weight ratios, ratios are still not as high as those of glass-reinforced structures. No additional data are available.

Although this weight penalty is unattractive for aircraft and missile applications, such systems appear extremely promising for other applications where higher strength and modulus are required and weight is not quite as critical.

Synthetic organic fibers, such as nylon, saponified acetate, and polyester, have been little used. Most development work with such fibers has been done for classified atomic

H. I. Thompson Fiber Glass

***Edge-grain tape winding** is used with a high silica fiber (Refrasil) oriented at 90 deg to the axial direction for ablation hardware. Part is a rocket exit cone.*

TABLE 4—COMPARISON OF STEEL VS GLASS REINFORCEMENT FOR FILAMENT WINDING[a]

	Filament		Unidirectional Laminate		Cylinder Design Values				Sphere Design Values	
					Hoop		Longitudinal			
	Glass	Steel	Glass	Steel	Glass	Steel	Glass	Steel	Glass	Steel
Ult Ten Str, 1000 psi	200	450	140	315	93	210	47	105	70	158
Ten Mod of Elast, 10^6 psi	10	29	7.0	20.3	4.67	13.5	2.35	6.6	3.5	10.2
Total Elongation, %	2.0	1.6	2.0	1.6	2.0	1.6	2.0	1.6	2.0	—
Density, lb/cu in.	0.92	0.283	0.077	0.209	0.077	0.209	0.077	0.209	0.077	0.209
Strength-Weight Ratio, 10^6 in.[b]	2.17	1.59	1.82	1.51	1.21	1.0	0.60	0.50	0.91	0.75

[a]Values given for reinforced structures are modest typical values using an epoxy binder. Values for glass-reinforced structures are based on 84% glass content by weight; values for steel-reinforced structures are based on 94% steel by weight.
[b]Ultimate tensile strength divided by density. Source: Aerojet-General Corp.

energy applications and data are unavailable. Although strength-weight ratios of some such fibers (e.g., polyesters) are excellent, dimensional stability could be an important problem.

Tape winding — In addition to rovings, reinforcements in the form of tapes are used for "tape wrapping." This is actually a form of filament winding, primarily adaptable to cylindrical shapes. (The term "tape," which denotes a mechanically interlocked or woven fabric strip, should not be confused with the term "ribbon," often used to denote a number of rovings or filaments, with no fill threads, applied in a band during production winding.)

Probably the largest single use of tape wrapping is forming ablative insulation for missile hardware. Asbestos-felt tapes preimpregnated with phenolic resins are wound on mandrels to form rocket motor cases or exit or nose cone insulations. The tape is wrapped under little or no tension and cured by vacuum bag, pressure bag or matched die molding techniques. High silica fiber, such as Refrasil, is also used in tape wound rocket insulation.

End-grain tapes are a primary ablation material. End-grain tapes are tapes in which the fibers are arranged in a predetermined angle from the axial direction of the tape. After winding such tapes, the resulting orientation of individual fibers usually ranges from 90 to 30 deg to the surface depending on type of service. Angular orientation in the direction of gas flow provides maximum resistance to ablation, but makes it difficult to maintain consistent resin-fiber end ratio over a surface.

Woven tapes, of course, do not provide the maximum in strength since reinforcement is not unidirectional. A relatively new type of tape is a nonwoven resin-bonded fabric; the warp threads are pretensioned in a parallel configuration, and small fill threads are positioned all on one side of the warp threads and resin-bonded to them. This configuration essentially provides a ribbon of uncrimped roving or threads with a small proportion of fill threads. According to the producer, Coast Mfg. and Supply Co., the major benefit of such configurations for filament winding is that all the rovings are accurately prestressed to the same degree. The fill threads maintain this equal tension during fabrication.

Binder systems

Theoretically, if all the filaments in a wound structure are under pure tensile loads, a resinous binder is unnecessary from the structural standpoint. It should only be necessary to protect the fibers from degrading environments and interfiber abrasion during the "working" of the stressed structure.

In practice, however, the resin appears to be critical in obtaining maximum strength structures (e.g., epoxies provide maximum strengths, while it is difficult to obtain any degree of strength by winding with silicone resin). The actual function the resin serves in the structure is not clearly understood or agreed upon. The most widely held explanation is that since in practice it is virtually impossible to load each filament in a complex structure under equal tension, the resin serves to transfer stresses and distribute them equally among the filaments. Thus, three of the most critical requirements of the resin system would be: 1) ability to provide a strong resin-glass bond, 2) high shear strength, and 3) probably an elongation at least that of the glass filaments, i.e., 2-3%.

On the other hand, Brown, of Aerojet-General Corp., feels that distribution of stresses between wound layers may be more critical than between filaments of a layer. In this case, compressive strength of the resin system would be more important than, or equally as important as, shear strength.

Regardless of theory, the importance of the resin system has been rather clearly demonstrated.

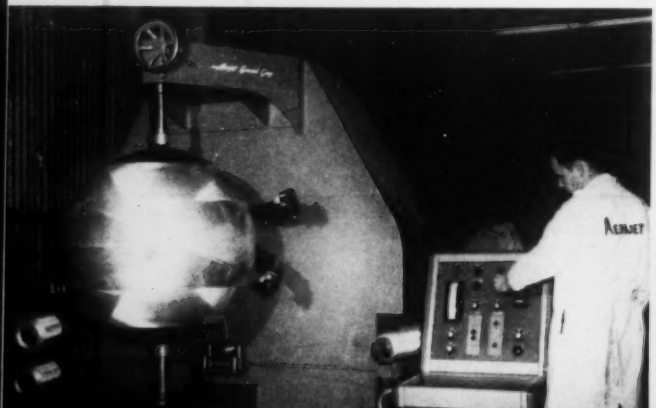
In selecting a resin system for filament winding, processing characteristics of the system are critical. Most production today is by "wet winding" techniques. Thus the resin system ideally must be a liquid at room temperature, have a relatively low viscosity (e.g., 500-1000 cps), have a long pot life, and be 100% solids. These requirements have limited the bulk of the work to epoxies and polyesters. (Wet vs dry winding is discussed in the later section on processing.)

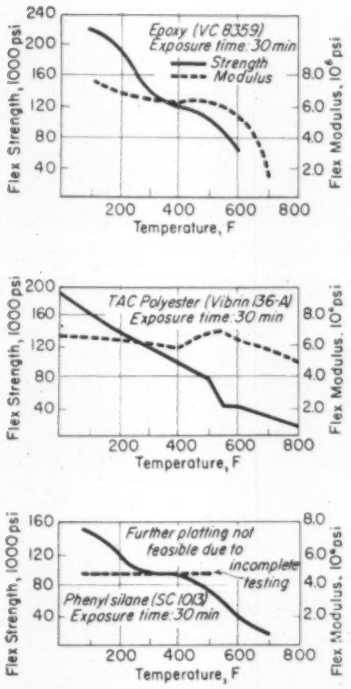
General purpose resins—About 90% of the resins used in filament winding today are conventional bisphenol A–epichlorohydrin epoxies, e.g., Shell's Epon 828 or 820. Usually these are cured with amine hardener systems which provide good room temperature processing characteristics. They are, of course, limited in long term heat resistance to maximum temperatures of 200-300 F, depending on the strength requirements. Most published data have been developed from structures using these materials.

A limited amount of polyester resin is being used, primarily for electrical applications such as aircraft radomes. Most of these polyesters are of the TAC (triallyl cyanurate) type, such as Naugatuck's Vibrin 135 and 136. When used properly, they provide the necessary processing characteristics coupled with radar transparency and consistent, low dielectric constant and loss factor. They also provide good heat re-

Typical processes *are represented by the 40-in. spherical winding machine at left and the 37-in. dia helical winding machine at right (constructed for the AeroRove Process).*

Aerojet-General





2 Flexural strength *and flex modulus of filament wound specimens of a new epoxy, a phenyl silane and a TAC polyester resin exposed to temperature as high as 700 F. Although these curves are not design data, they are good indicators of comparative performance.* (Brunswick)

sistance in the 400-500 F temperature range.

Some conventional styrene-type polyesters are used for such applications as rocket igniter baskets which need function only during ignition of the rocket motor. But for the most part the future of polyesters in filament winding appears to lie primarily in electrical applications. (A new low-loss resin for filament wound electrical structures is described on p 8.)

High temperature systems—Indicative of the state of the art, many engineers involved in filament winding of aircraft and missile hardware indicate that they have many more pressing problems than upping the heat resistance of their systems through evaluation and use of newer resins. They point out that their present applications do not require long term heat resistance above about 200-250 F: pressure vessels are used in internal, protected areas —structural missile components are protected by ablative insulating systems.

On the other hand it is clear that boosting the long term heat resistance of the structural filament wound composite could pay off in substantially lower weight by reducing the thickness of insulation required.

Two new epoxy resin systems appear to offer both the required processing characteristics and improved heat resistance. They are 1) an epoxy novolac resin introduced early this year by Dow Chemical Co., designated DEN 438 (see M/DE, Jan '60), and 2) an epoxy system based on Union Carbide Chemical Co.'s peracetic acid diepoxides, introduced several months ago by Brunswick Corp. and designated VC 8359 (see M/DE, Apr '60).

Although data are unavailable at time of writing from Narmco on the resin evaluation work they have done for the Air Force, reports indicate that they found the epoxy novolac system provided the best balance of processing characteristics and heat resistance. (Narmco has not yet evaluated the newer VC 8359). Specific hardener systems used with the epoxy novolac system have not been revealed, and data are extremely limited. Although heat distortion temperatures are only useful as indicators and for comparison, 264-psi heat distortion temperatures in the range of 500 to 570 F have been reported by Dow for DEN 438 with methyl nadic anhydride cures; 300-400 F for amine cures. The material is reported to retain a substantial proportion of initial strength after exposure to 500 F.

The newer peracetic acid-diepoxide based system also appears highly promising, but has not been fully evaluated for winding as yet. In tensile and flexural strength tests on standard 181 glass cloth laminates, the material has shown excellent strength retention after exposure to 500-550 F. The material meets the 500 F performance specification under MIL-R-9300-A, Type II parts. It is now the only resin approved for this specification. Fig 2a, b, and c show effects of temperatures up to 700 F on flexural strength and modulus of the new VC 8359 epoxy, a TAC polyester (Vibrin 136-A), and a phenyl silane (SC 1013).

These data are particularly interesting because they are based on filament wound, unidirectional specimens loaded parallel with direction of fiber. Although flexural strengths are not useful in design, particularly when obtained on unidirectional specimens (because failure is usually in shear), such data are useful from the standpoint of resin comparison.

Phenolics, phenyl silanes, silicones a problem—Proof of the importance of the resin system in filament wound structures are the results that have been obtained with heat resistant phenolics, phenyl silanes and silicones. The theory that glass is the primary structural member in the composite and the resin merely protection for the glass indicates that these three high temperature resin systems should provide the ultimate in a high temperature composite. Unfortunately this is not the case at present.

Phenolics and phenyl silanes polymerize by a condensation reaction which liberates water. A good, consistently intimate resin-glass bond has always been difficult to obtain with phenolics using the lower pressure forming techniques for reinforced plastics. It is also a problem with the newer phenyl silanes. This problem has been overcome in low pressure reinforced plastics processing techniques by utilizing the material in the form of B-staged prepregs. Although modifications of technique have permitted some wet winding of the material, results have not been exceptionally good.

In the case of silicone resins, solvent-free 100% solids systems have been developed recently, but the inherent mechanical strength of silicones is quite low. Filament wound structures made with such silicone resins have provided extremely low strengths. The reason for this is not too clear.

According to Dow Corning, one of the primary problems is the preparation of glass roving. Silicones do not adhere well to glass that has been finished with many of the conventional coupling agents (or finishes) customarily used. Optimum bonds are obtained on heat-cleaned glass. Multi-end roving is difficult to clean completely so that all the size is removed from each filament; consequently, impregnation of the roving does not provide a good bond with each individual filament.

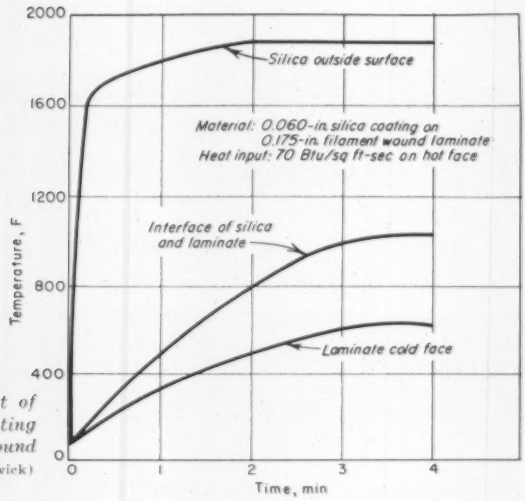
Prepregs may be the answer—The solution to these problems with phenolics, phenyl silanes and silicones may be found in the use of preimpregnated B-staged roving. Although some such roving has been

available, its use is still new and to a great extent untried. But many suppliers of prepreg materials are investing heavily in equipment for preimpregnating roving for filament winding. They feel that a substantial market exists for prepregs, and particularly in prepregs of resins such as phenolics, phenyl silanes and silicones which are difficult to wet wind successfully. The phenolics and phenyl silanes would probably be used for maximum strength at high temperatures; the silicones for uses requiring relatively low strengths, but excellent dielectric properties on exposure to heat.

Inorganic binders—There is continuing interest in the use of colloidal alumina, zirconia or silica slurries to form ceramic binders or matrixes for E glass filaments in extreme high temperature structures. Such matrixes or binders are "cured" by low temperature chemical fusion techniques involving temperatures of only about 1000 F.

Although some very limited successes have been reported (see M/DE, Nov '58, p 141) the approach does not appear highly promising. The major problem, according to V. Chase of Brunswick, is the extremely high modulus of the ceramic materials. The matrix should have a modulus lower than that of the reinforcement to effectively distribute the load among the filaments. Present work centers around finding lower modulus matrix materials; or conversely, finding higher modulus reinforcements.

The most success achieved with ceramics in conjunction with filament wound structures has been in coating the wound structure with a sprayed ceramic coating. Brunswick has sprayed radome structures with silica coatings, producing the insulating effect shown in Fig 3. This graph compares hot face, interface and cold face temperatures for a filament wound laminate protected by an 0.060-in. silica coating. The data were developed for Brunswick by Southern Research Inst.



3 Insulating *effect of a sprayed silica coating on a filament wound laminate.* (Brunswick)

The filament winding process

Specific winding techniques and modifications to provide specific end results are well-kept proprietary secrets. Each winder naturally feels he has developed techniques which give him certain competitive advantages.

However, there are several basic considerations in winding that have a direct effect on the final part. Although space limitations do not permit a complete delineation of these, some of the most important are covered briefly in the following sections.

Wet vs dry winding

From the raw materials standpoint, three methods of winding can be used. Parts can be produced by 1) wet winding, in which the roving is fed from the spool, through an impregnating resin bath, and onto the mandrel, 2) dry winding, in which preimpregnated B-staged roving is fed either through a softening oven and onto the mandrel, or directly onto a heated mandrel, or 3) post-impregnation, in which the dry roving is wound on the mandrel and the resin is applied to the wound structure by brushing, or by impregnating under vacuum or pressure. This last technique is usually limited to relatively small parts, such as shotgun barrels, since thorough impregnation without the use of pressure or vacuum is difficult.

At present, wet winding is by far the most common method used. It is lowest in terms of materials cost, and for those producers equipped with plastics formulating facilities it offers the benefits of flexibility of resin formulation to meet specific requirements for different parts. Of course, the bulk of the organizations presently involved in filament winding are either aircraft or missile manufacturers or plastics fabricators, all of whom usually have relatively well-equipped plastics laboratories. Also, the developmental nature of the filament winding process has made resin formulation and experimentation mandatory.

On the other hand, wet winding imposes definite limitations on the resin systems that can be used. Systems must 1) be low in volatile content, to prevent gassing and bubbling within the wound structure, 2) be available within specific viscosity limits at room temperature to provide thorough saturation (heating

Rocketdyne

Ellipse *used to wrap-in end closures can be seen in the reinforcement of this part.*

must be used with some systems), and 3) have pot life long enough to permit preparation of large impregnation baths for optimum economy of production.

Also, when wet winding, tension of the roving must be altered as the diameter of the part increases if accurate control of resin-glass ratio is mandatory. If winding tension is not altered, resin content varies directly with diameter.

From the standpoint of the end user, the most important benefit of dry or prepreg winding is the variety of resin types that can be wound. Use of prepreg phenolic, phenyl silane, and silicone resins may offer a number of benefits in high temperature structures or where high temperature electrical properties are required.

Although materials costs for dry winding are naturally higher than those for wet winding, dry winding offers additional benefits in that 1) smaller shops do not require plastics formulation facilities, 2) close control over consistency of resin system and resin-glass ratio can be maintained, 3) preimpregnated roving can be quality controlled prior to winding, providing a high degree of reproducibility of quality from part to part.

An additional benefit in comparison with wet winding is that material can be supplied with a relatively high "tack" to permit winding on steeper slopes without the roving sliding off.

Two winding patterns

Two basic patterns can be used in winding, each having a number of variations. Each pattern can be used by itself, or combined with the other to provide the desired type of stress distribution in the part.

The first method is circumferential winding, involving "level" winding of circumferential filaments interspersed with longitudinal layers of reinforcement.

By this method, the impregnated roving, either in single or multiple strand bands or ribbons, is laid down on a rotating mandrel at approximately 90 deg to the axis of rotation. The movement of the carriage that is directing the roving onto the mandrel advances the band of roving a predetermined amount each revolution depending on the thickness of wrap desired.

The resulting circumferential windings provide strength only in the hoop direction; longitudinal strength is supplied by applying, either by hand or machine, longitudinal rovings, bands of rovings or woven fabrics. When such longitudinal reinforcements are applied by hand, usually a unidirectional tape is preferred to provide sufficient pretensioning of the filaments. In the Strickland B process, used by Brunswick, longitudinal rovings are machine-applied, and can produce open-end structures.

The second widely used winding pattern is helical winding. In this technique, the mandrel rotates while an advancing feed places the roving or band of roving on the mandrel. But in helical winding, the feed advances much more rapidly than in circumferential winding, the result being that the rovings are applied at an angle of anywhere from 25 to 85 deg to the axis of rotation. In helical winding, no longitudinal filaments need be applied, since the low winding angle provides the desired longitudinal strength as well as the hoop strength. By varying the angle of winding, many different ratios of hoop to longitudinal strengths can be obtained.

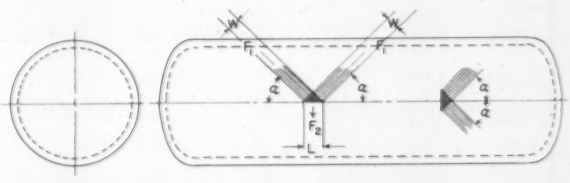
Circumferential winding provides maximum strength in the hoop direction, but does not permit winding of slopes over about 20 deg when wet winding or 30 deg when dry winding. Nor does it permit effective integral winding of end closures. For either steep slopes or inclusion of end closures, helical winding, or a combination of helical and circumferential winding, must be used.

Generally, in helical winding, single circuit winding is used, i.e., the roving or band of roving makes only one complete helical revolution around the mandrel from end to end. Young Development holds a patent on multicircuit winding, which permits a greater degree of flexibility in angle of wrapping and length of cylinder. According to Young, the optimum helix angle to provide a balanced closed cylindrical structure is 54.75 deg. (The netting analysis used to derive this angle is summarized in the box below.)

Other variables

Many other process variables affect the properties of the final structure. Among these are roving end count used, amount of tension applied to filaments during winding, resin-glass ratio and void content.

Little evaluation work on the effects of these variables has been reported. In general, end count used is usually 12 or 20, average tension used in winding is about ¼ lb per



How Young Derives Optimum Winding Angle

Below is a simplified derivation—on a wall thickness basis—of the optimum helix angle for a balanced structure in a cylinder.

S = Unit strength of parallel filament system, psi

S_G = Unit strength of cylinder in girth direction, psi

S_L = Unit strength of cylinder in longitudinal direction, psi

T = Wall thickness of cylinder, in.

α = Helix angle, deg

$F_1 = SW \cdot T/2$

$F_2 = \sin \alpha \cdot SWT$

$S_G = F_2/LT$

$L = W/\sin \alpha$

Thus $S_G = \dfrac{\sin \alpha \cdot SWT}{(W/\sin \alpha) \cdot T} = S \cdot \sin^2 \alpha$

Similarly, $S_L = S \cos^2 \alpha$

For a cylinder of 2:1 strength ratio:

$2/1 = S_G/S_L = S \cdot \sin^2 \alpha / S \cdot \cos^2 \alpha$

Thus $\sin^2 \alpha / \cos^2 \alpha = 2 = \tan^2 \alpha$

And $\alpha = \tan^{-1} \sqrt{2} \cong 54.75$ deg

end, and glass-resin ratio appears to average about 80-20. But the specific effects of altering each of these variables has not been reported quantitatively.

The article by Miller and Carter of Brunswick, starting on p 144, reports results of a study of the effects of such variables. Their data refer to polyester systems, but the bulk of it should apply qualitatively to epoxy systems.

Test methods—key to useful design data

One of the major problems in developing design data for any engineering material is correlating the results of standard tests with the performance of the material in its final shape. This is an even more critical problem with filament winding, since the load-bearing characteristics of the material are built in as the part is formed.

TABLE 5—AXIAL COMPRESSIVE STRENGTH OF FILAMENT WOUND CYLINDERS[a]

Type of Resin	Type Structure[b]	Temp, F[c]	Buckling Stress, 1000 psi
Phenolic A	C	75	14.8-22.2
		950	6.2-8.5
Phenolic B	C	950	18.2-24.2
Epoxy A	C	75	30.9-36.1
	H	75	4.6-20.6
Silicone	C	75	13.5
		950	4-5.1
Phenolic	PM	250	6.5-6.9
		950	3.6-6.4

[a]Surface reached test temperature in 10 sec; loading rate was 3000 lb per sec.
[b]C = circumferentially wound, H = helically wound, PM = pressure molded. Molded data are given for comparison.
[c]250 F test is steady state; 950 F test is transient heating.
Source: Hughes Aircraft Co.

TABLE 6—BENDING STRENGTH OF FILAMENT WOUND PHENOLIC CYLINDERS[a]

Structure, Test Temp	Loading Rate, lb/sec	Bending Str, psi
Circumferentially Wound		
At 250 F	220	6250
	235	5710
	260	6105
At 950 F	211	2400
	227	2400
	312	2350
Pressure Molded (for comparison)		
At 250 F	75	486
	101	1012
	125	405
At 950 F	44	530
	52	170

[a]Test temperature reached in 10 sec. 250 F test is steady state; 950 F is transient heating.
Source: Hughes Aircraft Co.

The conventional approaches

Because the filaments are the primary load-bearing members, and they are designed to be stressed only in tension, much of the work in developing meaningful tests for filament wound reinforced plastics has been aimed at deriving practical tensile strength values in composite structures. Since the tensile strengths of the filaments are relatively well-known, the primary purpose of testing is to determine how well the resin is permitting the filaments to carry the load efficiently.

Tensile specimens cut from cured filament-wound shapes are usually curved because of the nature of the structure. Curved specimens will not provide tensile failures if pulled in tension. Also, failures of standard ASTM tensile specimens reinforced with unidirectional filaments are in shear rather than tension. Consequently, such tests as the NOL Ring Test and special test specimens for use with ASTM and L-P-406 standard test methods have been developed, as well as a number of proprietary methods.

For final proof testing of structures, of course, service or simulated service testing should be performed. Hydrostatic burst testing either an actual or scaled component, or bursting a cylinder with floating seals, provides the most meaningful data.

Evaluating other loading conditions

Most applications for filament wound structures—such as pressure vessels and rocket motor booster cases—have involved internal stressing. For some military, and many industrial applications, the behavior of such structures under compressive or flexural loading conditions must be known. Relatively little testing has been done to obtain these data.

Tables 5 and 6 show some of the relatively few data available describing this type of performance. These data, developed by Hughes Aircraft Co., show 1) room and high temperature buckling strengths of cylinders of phenolics, epoxies and silicones wound both circumferentially and helically when stressed in axial compression, and 2) strength of circumferentially wound phenolic cylinders at elevated temperatures when exposed to pure bending stresses.

Test methods, as described by *Hribar and Tsao* of Hughes, were as follows: Tubes were 0.125 in. thick, 0.4 in. i.d., and 18 in. long. Ends were wound thicker to prevent local end failures. Heat source consisted of GE T-3 radiant heat lamps controlled to within ±10 F. Approximately 10 sec were required to reach test temperature, another 5 sec to achieve temperature stability, and 10 sec to make contact between test machine and specimen. Schematic drawings of the test setup, as well as photos of specimens after test, are shown in Figs 4 and 5.

Which tests are best?

Because of 1) the specialized nature of the test methods which have had to be developed for evaluating filament wound structures, and 2) the proprietary nature of the technology, there is little agreement between experts in the field as to the most meaningful and practical series of test methods to use.

However, each fabricator has developed—to varying degrees of satisfaction—certain formalized test procedures for materials evaluation. An example of one detailed, effective program for materials selection and evaluation is Rocketdyne's, detailed in the article on the following pages.

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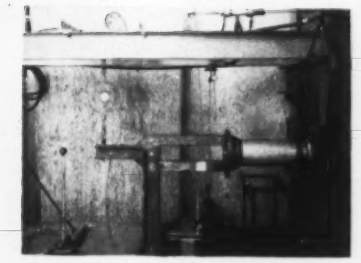

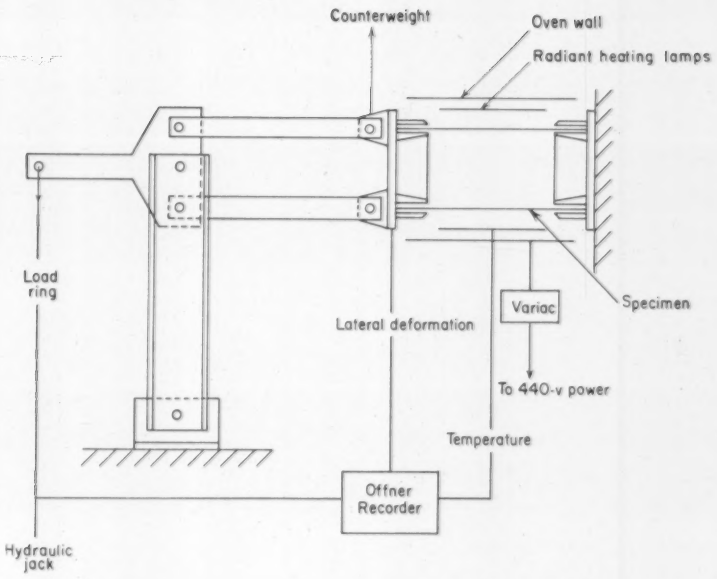

4 ***Pure bending strength*** *of cylinders is measured by this apparatus. Photo at bottom left shows typical type of failure under pure bending of circumferentially wound specimens.* (Hughes Aircraft)

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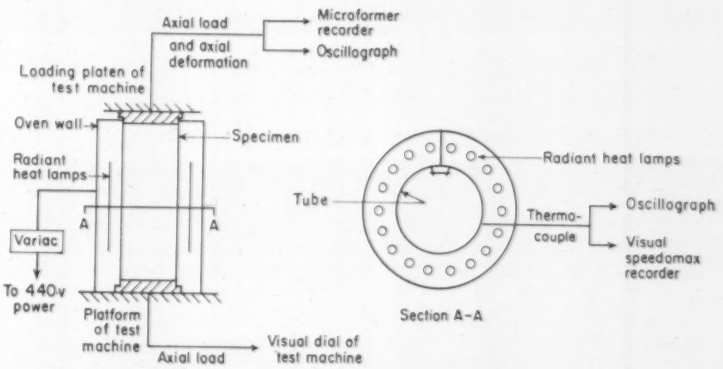
Acknowledgments

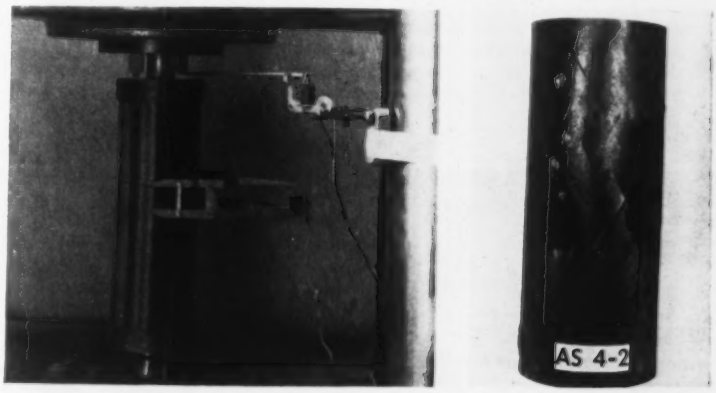
Particular thanks are due G. Epstein, Aerojet-General Corp.; R. E. Young, Hercules Powder Co.; D. V. Rosato, Plastics Plant, Raytheon Corp., and J. E. Lieb and E. H. Jaffe, Rocketdyne, for reviewing the manuscript.

The assistance of personnel and literature of the following organizations is also gratefully acknowledged:

Aerojet-General Corp., Sub. of General Tire & Rubber Co.
Amercoat Corp.
Apex Reinforced Plastics Div., White Sewing Machine Corp.
Boeing Airplane Co.
Brunswick Corp. (formerly Brunswick-Balke-Collender Co.)
Douglas Aircraft Co.
H. I. Thompson Fiber Glass Co.
Hughes Aircraft Co.
Narmco Industries, Inc., Sub. of Telecomputing Corp.
Owens-Corning Fiberglas Corp.
Raybestos-Manhattan, Inc., Reinforced Plastics Dept.
Rezolin, Inc.
Rocketdyne, Div. of North American Aviation, Inc.
A. O. Smith Corp.
U. S. Polymeric Chemicals, Inc.
Wright Air Development Div., Air Research and Development Command (USAF)
Young Development Div., Hercules Powder Co.



5 ***Buckling strength*** *of filament wound cylinders is determined by this test apparatus. Specimen at bottom right shows failures typical of a helically wound tube under axial compression.* (Hughes Aircraft)



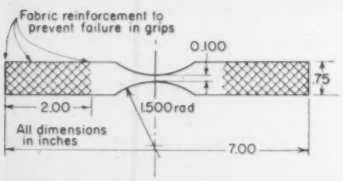
1 ***Flat, unidirectional*** *flexural and tensile specimens are cut from these specimens wound on the three-part aluminum mandrel shown in center.*

PART 2

How to Evaluate Materials for Filament Winding

by J. H. Lieb, *Senior Research Engineer, and* **E. H. Jaffe,**
Research Engineer, Rocketdyne, Div. of North American Aviation, Inc.

■ The important properties of resin systems used for filament winding are: 1) the proper chemical and physical characteristics to permit the resin to penetrate the fiber bundles and protect the fibers from environmental attack and abrasion, 2) the proper modulus and strength, and 3) the ability to bond to individual filaments and insure intimate contact. Ordinary test methods used for glass-reinforced plastics are insufficient to evaluate these characteristics in filament wound structures. Consequently a procedure must be established combining some standard test methods with specialized methods and specialized test specimens to predict how the resin will behave in a filament wound structure.



2 ***Special unidirectional*** *tensile specimen provides failures in tension in the necked unidirectionally reinforced area.*

The overall test sequence and procedures used at Rocketdyne are outlined in Table 1. The system proceeds from simple, rapid, inexpensive screening tests on the resin system, to more involved, more expensive testing of filament wound specimens, and finally to the evaluation of the performance of reduced scale and full size parts.

Resin screening

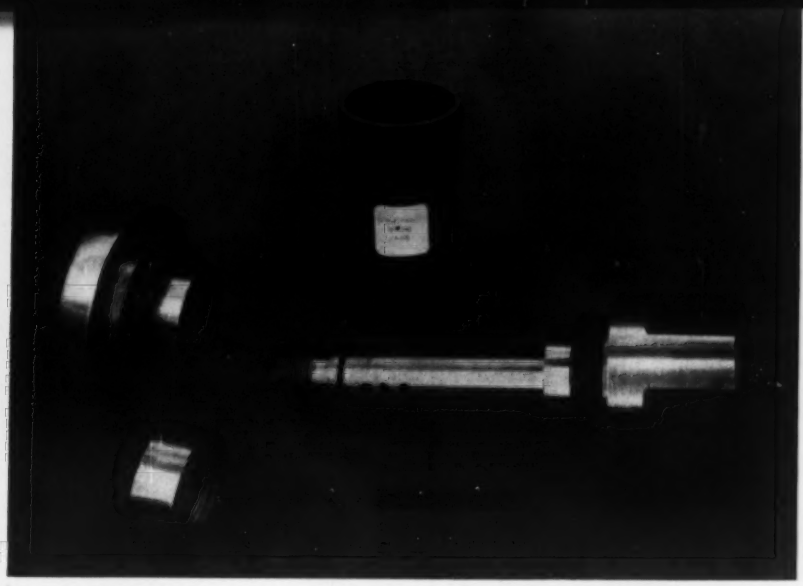
Initial screening tests on resin are only carried out where wet winding is planned. The tests are all standard ASTM or L-P-406 test methods designed to eliminate as economically as possible resin systems that are wholly inadequate.

The wet resin system is first tested by standard ASTM methods to determine whether or not it will fit Rocketdyne's wet winding method. A target viscosity range for the catalyzed resin system is 500-1000 cps at room temperature, although wet winding can be performed under certain circumstances at viscosities as high as 10,000-15,000 cps. For resin systems with viscosities above that of the target range, viscosity-temperature curves are plotted to determine if elevated temperature winding can be used.

At this time, the pot life of a 1-qt sample is determined at the winding temperature selected, and a viscosity-time curve plotted. If the resin system viscosity exceeds 10,000 cps in less than 120 min the system is rejected.

Resin systems selected from this screening are cast into specimens using a range of cure cycles for standard heat distortion, Barcol hardness and flexural tests. These tests are used to determine the cure cycles that will provide maximum properties.

Standard 181 cloth laminates using 12 plies in a parallel layup are made and vacuum-bag or press cured. Laminates are tested by standard flexural tests at both room and elevated temperature, and after a 2-hr water boil. Results of such tests are of value only for general comparison with the large amount of such property data available in the literature. Possibly different rankings of strength reduction



3 Cylindrical *3-in. dia wound specimen, showing tie-bolt and seals for hydrostatic burst testing.*

would result from humidity cycling instead of the 2-hr boil test, but this effect has not been studied.

Evaluation of unidirectional specimens

Flat specimens—The next step in evaluation is the development of flat unidirectional test specimens. If prepreg roving is to be used for dry winding, this would be the first step of the test program.

At Rocketdyne, these laminates are wound with a single-strand 20-end roving on three 12 × 8-in., three-piece mandrel shown in Fig 1. The flexural laminate consist of 10 layers of roving only; the tensile laminate consists of 15 layers of roving with 4 plies of fabric added to the grip areas only, one fabric ply interspersed between each three layers of wrap. The center test section is thus completely unidirectional.

The rotational and traversing speeds of the winding machine are adjusted so that each turn lays down the roving strand immediately adjacent to the prior turn without overlap. Typical winding conditions for a single-strand, 20-end roving under 9 ± 1 lb of tension are 20 rpm rotational speed, and 0.17 ipm traverse speed.

After winding, the panels are wrapped in a separating film and press cured between rubber blankets at 80-100 psi. Pressure is required during cure of flat laminates to substitute for the pressure exerted by the reinforcement in winding a circular cross section. The proper curing pressure must be picked so that it results in specimens of pre-established resin content. In this case, resin content of 18-20% is used to provide panels having the same resin content as the 3-in. cylinders described later.

Following cure, the laminates are cut to form 1) two 8 × 12-in. panels which are machined to make standard 1-in. wide flexural specimens, and 2) the special tensile specimen shown in Fig 2. (Note that the neck area of the tensile specimen has been reduced from that of standard specimens; this reduction provides tensile failures during test.) Flexural and tensile tests are car-

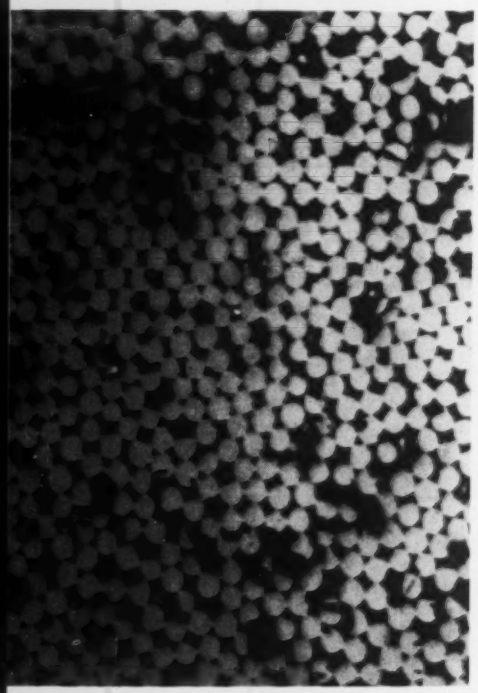
TABLE 1—EVALUATION TEST SEQUENCE

	Test Phase	Properties Evaluated	Samples Used	Test Methods
For Wet Winding	**1** Uncured Resin	• Visc-temp curve • RT pot life • Elev temp pot life	Liquid resin Liquid resin and curing agent	Brook field viscosimeter
	2 Cured Resin	• Heat distortion point • Flexural strength • Chemical compatibility	Cured resin castings	Standard ASTM and L-P-406 test methods as required
	3 Low Pressure Fabric Laminate	• Flexural strength, modulus • Tensile strength, modulus • Environmental resistance	181 cloth laminate (12-ply)	Standard ASTM and L-P-406 test methods
For Prepreg Winding	**4** Flat Filament Wound Test Panels	• Tensile strength, modulus • Flexural strength, modulus • Bearing strength • Interlaminar shear strength • Resin content • Environmental resistance	Rocketdyne unidirectional filament wound flat laminates	Standard ASTM and L-P-406 test methods (with special samples)
	5 Filament Wound 3-In. Dia Test Cylinders	• Burst strength • Resin content • Environmental resistance	Rocketdyne test cylinders	Rocketdyne test methods and standard ASTM and L-P-406 tests as required
	6 Prototype and Production Parts	• Burst strength • Resin content • Cross-section photomicrographs • Environmental resistance • Special performance requirements	Reduced scale and full size article	Test methods as required in equipment specifications

ried out by standard procedures.

The results of flexural tests do not provide design data but are used for comparative material evaluation, including resin systems, cure cycles and glass finishes, and for evaluation of process variables such as impregnating time and tensioning of reinforcement. Flexural tests are useful for these evaluations because they tend to exaggerate the differences between materials.

Results of tensile testing of laminates provide direct values for ultimate strength, modulus, and design allowables. The tensile specimens minimize differences between resin systems, but test results correlate well with design data determined from burst cylinders and prototype parts.



4 Cross-section *photomicrograph of filament wound specimen. Note packing of individual fibers.*

Cylindrical specimens—The final method of specimen testing is the hydrostatic bursting of 3-in. i.d. cylinders, shown in Fig 3 with the hydrostatic test fixture. The cylinder is 6 in. long, with a nominal wall thickness of 0.125 in. in the center section. It is wound circumferentially on a TFE fluorocarbon-coated aluminum mandrel using longitudinal fabric reinforcement (fabric reinforcement totals 0.040 in. in thickness). Extra layers of roving are incorporated at each end to prevent premature end-failure.

The test fixture includes rubber cup seals to prevent leakage and a center tie bolt to eliminate longitudinal loading during test.

A typical resin system fails at approximately 13,000 psi hydrostatic pressure. The wall stress, S_w is calculated from the formula:

$$S_w = PD/2t$$

where: P = burst pressure, psi
D = mean cylinder diameter, in.
t = wall thickness, in.

With a 13,000 psi bursting pressure, wall stress is found to be approximately 162,500 psi. If the 0.040-in. thickness of longitudinal fabric reinforcement is assumed to carry a negligible hoop load, this figure is equivalent to a hoop fiber stress of 240,000 psi for the circumferential winding.

This test, using water as a pressure medium, can be performed at both room and moderately elevated temperatures. For high temperature testing a modification has been developed making use of silicone "bouncing putty" as a pressurizing medium. Two free pistons are used in the cylinder. Load is applied to the protruding ends of the pistons forcing them against the "bouncing putty" which exerts pressure on the cylinder. Because of certain unknown differences between this test and the hydrostatic burst test, this test gives strength values that are 85% of those obtained hydrostatically.

In high temperature testing using the modified silicone method, a manifold heated by an air heat exchanger can produce cylinder wall temperatures up to 900 F.

Prototype and finished part

Using the resin system selected by the foregoing test sequence, and using the design allowables determined from the wound samples, the finished article is designed and prototype parts fabricated in either full or reduced scale. Prototypes are used for evaluation of wrap angle, end shape, fitting designs, attachment points and similar design factors. Depending on the application, full scale burst testing of complete prototypes may be carried out.

Prototype parts after test, are sectioned and small specimens mounted, polished and photomicrographed. Thus, the microstructure of the material, including resin distribution, wetting out, packing and extent of voids, can be studied. A typical photomicrograph is shown in Fig 4.

How the Rocketdyne method works

Table 2 shows four representative epoxy resin systems to which this test procedure was applied. The resins were intended for an application where wet strength and retention of strength at 160 F were the important requirements, and the curing temperature was limited to 200 F. Data in the table show that viscosity and pot life of all four systems meet initial wet resin requirements. In practice Resin C would have been rejected on the basis of its low heat distortion temperature.

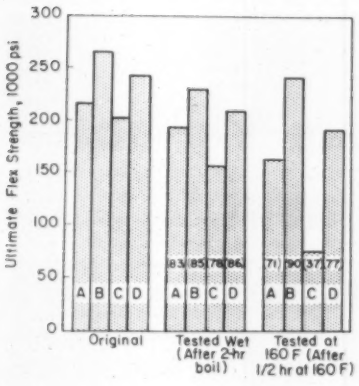
Fig 5 and 6 show results of flexural and tensile strength tests on the unidirectional specimens, and confirm the rejection of Resin C. The data also illustrate the exaggeration of differences in resin systems brought out by flexural testing, and the minimizing of differences by tensile testing. Fig 7 shows hoop tensile strengths derived from the cylindrical hydrostatic burst testing.

As a result of this sample evaluation system, Resin B was recommended, based on 1) the com-

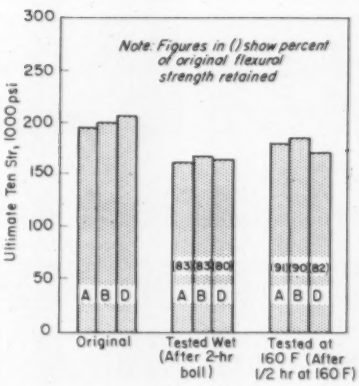
TABLE 2—PROPERTIES OF FOUR REPRESENTATIVE EPOXY RESIN SYSTEMS[a]

Resin System	Hardener[b]	Viscosity (RT), cps	Pot Life, min	Heat Dist Pt (264 psi), F[c]
A—Low Viscosity	Modified aromatic polyamine	600	320	181
B—Medium Viscosity	Primary alicyclic diamine	625	225	245
C—Low Viscosity	Primary aromatic amine mixture	600	360	140
D—Medium Viscosity	Modified aromatic polyamine	470	390	206

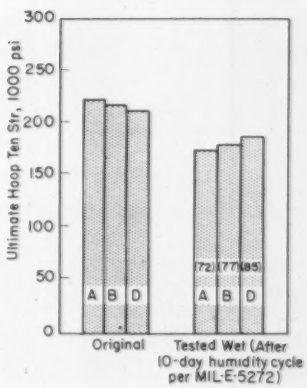
[a]All resins are bisphenol A-epichlorohydrin epoxies.
[b]Hardener used in system B is methane diamine. Others are proprietary.
[c]All systems cured at 200 F.



5 ***Flexural strengths*** *of flat unidirectional laminates made up from the various resin systems shown in Table 6. Note exaggeration of differences between resin systems.*



6 ***Tensile strengths*** *of unidirectional flat laminates made up from resin systems shown in Table 6, with the exception of C which was eliminated by results of flex tests. Note minimization of differences between resin systems.*



7 ***Hoop strengths*** *determined from 4-in. dia cylinders under hydrostatic burst testing.*

paratively high heat distortion temperature shown, 2) the comparatively high flexural strengths shown, particularly after 2-hr boil and exposure to 160 F, 3) the superior tensile strengths after exposure to water and heat (though initial strength was slightly lower than that of Resin D), and 4) the moderately good hoop strengths shown in Fig 7. Resin D was second choice.

Other test methods . . . pros and cons

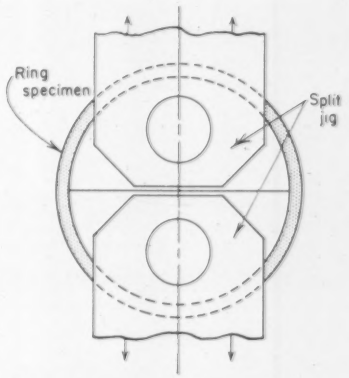
A number of different organizations have developed a variety of special filament wound samples for materials evaluation. These have been developed to overcome the inherent drawbacks of hydrostatic burst testing, which include 1) high cost—one 3-in. cylinder costs about the same as one flat filament wound panel from which approximately 20 specimens are obtained, 2) complications of method—it frequently requires use of hazardous test cells and other expensive installations, 3) difficulties in determining modulus, and 4) limited scope—hydrostatic burst is designed primarily to provide hoop strength values and does not permit accurate measurement of other types of loading such as bending, compression, shear and bearing.

Ring tests—Several variations of the basic NOL (Naval Ordnance Laboratory) Ring test are used. The NOL specimen is a 3-in. dia ring ¼ in. wide and ⅛ in. thick. The ring is fitted with two semicircular jigs which fit snugly into the i.d. of the ring, as shown in Fig 8. The ring is then broken by tensile loading applied to the split insert in a universal test machine. Small sections can be cut from the ring for testing in flexure and shear.

Another fabricator has developed a series of modifications of standard test procedures, all of which can be run with samples cut from a single 9-in. dia, 17-in. long cylinder having a wall thickness of 0.375 in. Rings ½-in. wide are cut from the cylinder and tested in a manner similar to the NOL test. Also, various rectangular samples are cut for longitudinal tensile, compressive, flexural, bearing and shear tests.

Advocates of the ring test make much of the fact that the construction of the specimens comes closest to that of the actual parts. Though this is true, the authors feel that this benefit is negated by the facts that 1) bending must be introduced to break such specimens in tension and 2) an unknown frictional factor is introduced by the sliding of the test jig on the i.d. of the ring. For this reason we feel that the flat unidirectional tensile sample and the hydrostatic cylinder are superior for tensile determinations.

Testing of reinforcements—The major problem in evaluating reinforcing materials separately from a reinforcement-resin system is the inability to load them in the same manner as they are loaded in the composite. Hence, testing of reinforcing, especially glass rovings, is limited by the fact that failure in dry roving bundles is apt to occur sequentially, from fiber to fiber.

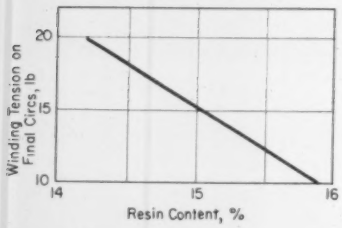


8 ***NOL Ring Test*** *setup shown schematically. Modifications of this test primarily involve only altering the specimen size.*

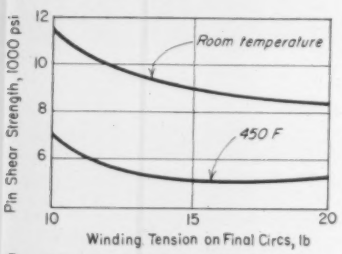
Pretensioning of the fibers and wrapping around a capstan-type grip has been the most successful method developed so far to overcome this drawback. But the large spread in results from one test to the next indicates that this is far from the complete answer. One promising method is the use of an integrating device to measure the total work required to break a known cross section of glass fibers, thereby allowing for sequential failure.

Reinforcing materials other than glass, such as quartz, high silica fibers, fine metal wires, or fibrous refractories, presents the same evaluation problem as glass fibers. The problem is actually more severe because of the abrasive nature, low strength and extreme hardness of such materials.

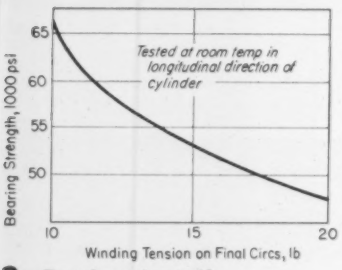
Effect of winding tension on . . .



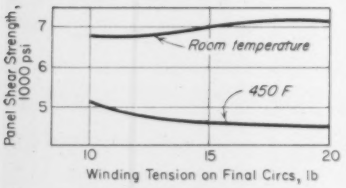
1 ***Resin content.***



2 ***Pin shear strength.***



3 ***Bearing strength.***



4 ***Panel shear strength.***

PART 3

How Process Variables Affect Filament Wound Plastics

by S. A. Miller, *Chief R&D Engineer, and* **J. S. Carter,** *Senior R&D Engineer, Brunswick Corp.*

■ Few data are available on the effects of materials and process variables on service properties of filament wound structures. In order to design the most effective structure with this relatively new process these effects must be known.

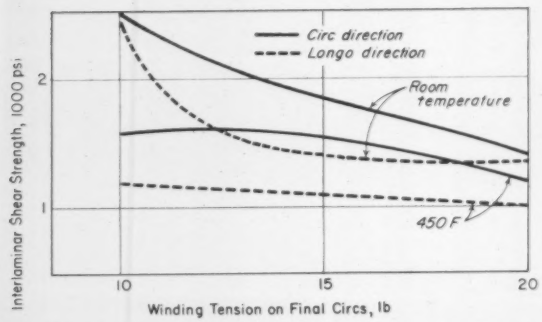
The data here summarize the results of an evaluation of the effects of 1) winding tension, 2) roving end count, and 3) resin content on mechanical properties of filament wound TAC polyester (Naugatuck's Vibrin 135) structures. Bear in mind that data were obtained on specimens produced by Brunswick's Strickland B process, which is a circumferential and longitudinal winding technique. Orientation of the filaments from one ply to the next in the final structure is essentially 90 deg. (Specimen preparation and test methods are described at the end of this article.)

Effects of winding tension

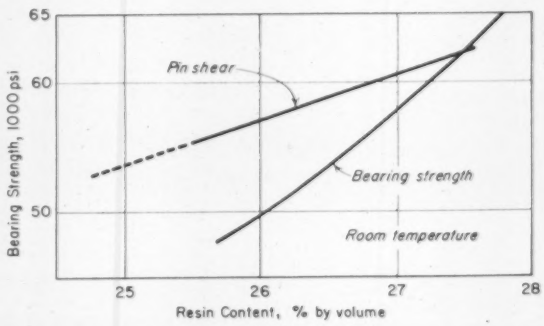
Winding tension indirectly affects all properties to some extent with the exception of panel shear. The resin content as affected by winding tension appears to have more influence than the degree of tension itself.

Three cylindrical specimens were wound, using 30-end roving, by applying a tensioning gradient of 5 lb on each subsequent circumferential layer ending with tension on the outer circumferential winding as follows: 10 lb on the first cylinder, 15 lb on the second, and 20 lb on the third. The effect of this winding tension on resin content is shown in Fig 1.

Pin shear vs winding tension at room temperature and 450 F is shown in Fig 2. Note the decrease in pin shear strength with increasing tension. Pin shear strength would be expected to increase with increasing tension, all other variables being constant. However, as Fig 6 later shows, pin shear strength increases with resin content; evidently the reduction of pin shear with increased tension is primarily a result of the decreased resin content



5 ***Interlaminar shear strength*** *as affected by winding tension.*



6 ***Effect of resin content*** *on pin shear and bearing strength.*

produced by the higher tension. The effect of resin content would not be as prominent in higher viscosity resins or B-staged prepreg rovings, where greater tension would be required to produce flow.

Fig 3 shows a similar relationship between bearing strength and winding tension. This decrease is also probably due primarily to decreasing resin content, as indicated by Fig 6.

Panel shear both at room temperature and 450 F showed no particular sensitivity to tension, as shown in Fig 4. Thus resin content appeared to have no appreciable effect.

Fig 5 shows only slight effect of tensioning on interlaminar shear strength, measured both circumferentially and longitudinally. The effect is particularly minor when measured at 450 F. Results indicate that small volume differences in resin content did not affect the strength. The slight superiority of strengths in the circumferential direction appears to be due to the nature of the specimen rather than any mechanical default in the longitudinal specimens. (There are four layers of filaments parallel to the test direction in circumferential specimens; three layers in longitudinal.)

Effects of end count

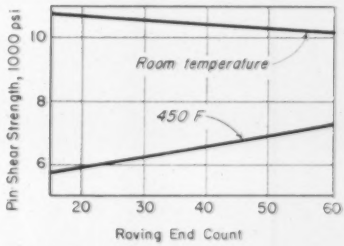
The process variables introduced by altering end count, such as handling characteristics, winding speed, tension uniformity, etc., appear to have greater influence on properties than the number of ends itself. From the following data, we conclude that as long as the same primary construction is maintained and process variables are held constant, the end count used will have no effect on mechanical properties.

Four cylindrical specimens were wound using 16, 30, 40 and 60-end roving under comparable tension per end. Such winding provides specimens with equal numbers of filaments in a cross section; thus results would show only effects of process variables.

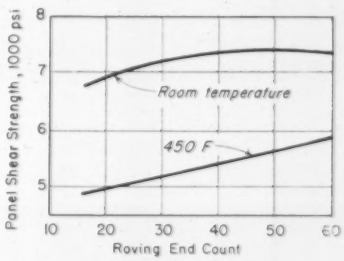
As shown in Fig 7 and 8, pin shear and panel shear strengths were not appreciably affected by end count. The slight change in properties was probably due primarily to the greater ease of fabricating with roving of higher end count. No apparent effect of resin content was noted.

Fig 9 shows the surprising increase in bearing strength with increased end count. Unexpectedly, the 30-end-count roving gave bearing strengths about 3000 psi higher than the 40-end, although the general

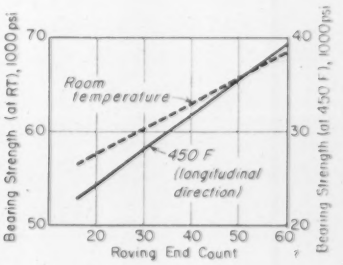
Effect of roving end count on . . .



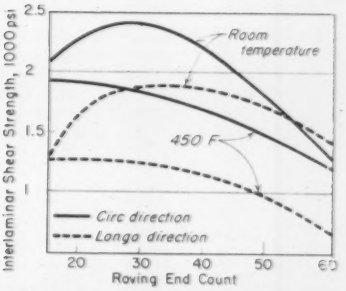
7 ***Pin shear strength.***



8 ***Panel shear strength.***

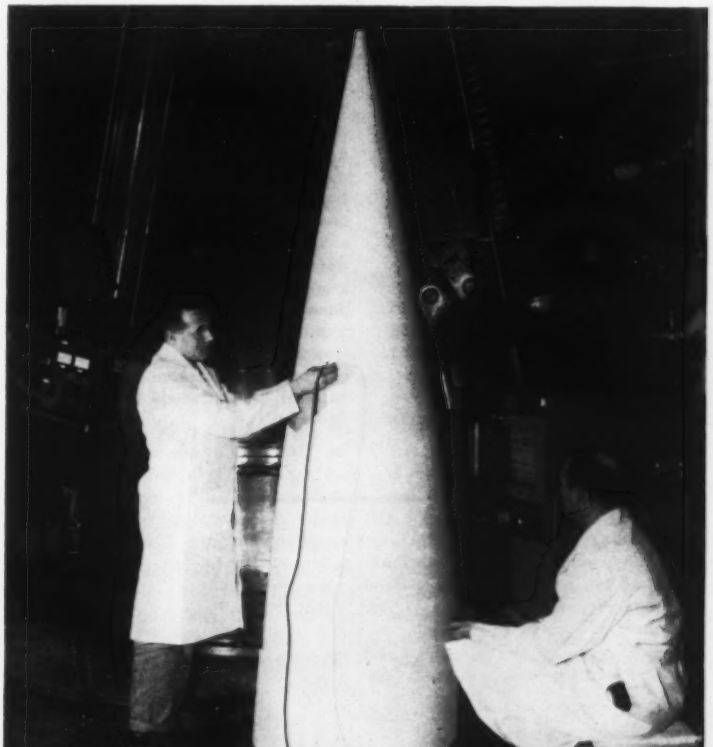


9 ***Bearing strength.***



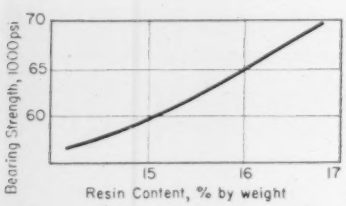
10 ***Interlaminar shear strength.***

High temperature radomes *are a major application for filament winding. This structure is being tested for electrical thickness.*

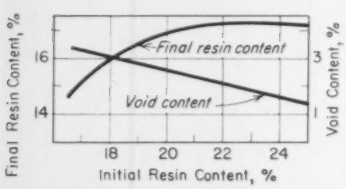


trend was increased strength with increased end count. However, plotting bearing strength vs resin content (see Fig 11) showed a more direct relationship, with bearing strength increasing, of course, with increasing resin content. Thus end count has only a slight effect, if any.

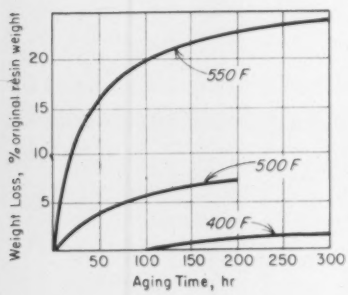
Interlaminar shear strength vs end count is shown in Fig 10, tested both circumferentially and longitudinally, and at both room temperature and 450 F. The higher values for circumferential specimens again were the result of specimen construction.



11 ***Effect of resin content*** *on bearing strength.*



12 ***Effect of initial resin*** *content on final resin content and void content.*



13 ***Effects of heat aging*** *on weight loss (based on percentage of initial resin weight).*

The increase and then decline of interlaminar shear is probably due to the winding technique used. Since the winder used had been adapted to 30-end roving, the lower and higher end counts were more difficult to apply evenly to the cylinder, the lower count rovings tending to flatten out and separate on the roller and the higher count rovings tending to bundle.

Effect of initial resin content on final resin and void content

Initial resin content in the roving appears to have no effect on physical properties of the finished laminate, since the final resin content is essentially the same under equal tensioning. However, void content can be markedly reduced by increasing initial resin content.

Four flat panels were fabricated under equal tension from 30-end roving using initial resin contents of 16, 18, 20 and 25% (±1%). Fig 12 shows initial resin content vs final resin content and void content. Note that after reaching approximately 20% initial resin content, flow of resin from the laminate was about the same. Consequently, under the same tension, the final resin content cannot be increased by increasing initial resin content.

However, increasing initial resin content did reduce void content substantially.

Weight loss of wound polyester

The data above, though obtained from filament wound polyester specimens, would probably apply qualitatively to structures using other resin systems. However, as a part of this evaluation system, measurements of weight loss caused by high temperature aging were also made. These are applicable only to the specific polyester system used in the tests.

Fig 14 shows weight loss, in percentage of original resin weight (not laminate weight), vs aging time at 400, 500 and 550 F. At 400 F, weight loss was negligible, the slight loss probably being caused by loss of volatiles rather than by carbonization. At 500 F, weight loss increased but after 200 hr was still only 7% of original resin weight. Considering this loss in resin weight as a part of the total laminate, an overall weight loss of 1.25% resulted.

At 550 F weight loss was considerable, due to excessive volatilization and carbonization. The resin weight loss after 300 hr at 550 F would probably be great enough that the specimen would not maintain structural integrity under load.

Test specimens, methods

Cylinders and flat panels were wound on an experimental winding machine using Garan finish and Naugatuck Chemical Co.'s Vibrin 135 resin with 2% benzoyl peroxide. All roving had an initial resin content of 18 ±1% with the exception of the specimens prepared to evaluate initial resin content.

Both cylinders and flat panels were fabricated in alternate construction—one circumferentially wound layer, one longitudinal wound layer—with each layer having the same 0.0126-0.021-in. thickness. An additional three circumferential windings were added on cylindrical and flat panels to maintain tension during cure, and were then ground off to the prescribed thickness.

All specimens, with one exception, were cured as follows: 1 hr at 275 F, 2 hr at 350 F, 1 hr at 400 F, and 2 hr at 450 F. The other cylinder was cured as follows to study the effect of cure cycle: 1 hr at 275 F, 3 hr at 350 F, 1 hr at 400 F, and 5 hr at 450 F.

Panel shear, interlaminar shear, bearing and pin shear were measured on five specimens at each temperature. Tests were performed in accordance with Brunswick Corp. test procedures except that flexural tests were performed on an 8-in. span rather than a 4-in. span.

The test methods standardized upon by Brunswick include some modifications of standard methods. Specific details of the methods are available from Brunswick. As the importance of the data given here is primarily qualitative in nature, details of test methods have not been included.

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first in silicones

Dow Corning

SILICONE NEWS

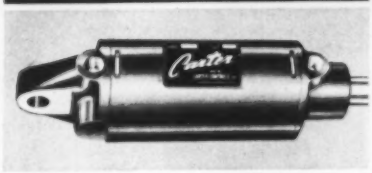
for design and development engineers • No. 76

SILICONES OPEN NEW MARKETS

Silicones provide the extra measure of performance that frequently helps open new markets for established products. A good example: the air and hydraulic cylinders manufactured by Carter Controls, Inc., Lansing, Illinois.

Carter has been able to extend the serviceability range of its cylinders from a maximum of 250 F to 500 F . . . through the use of silicone rubber seals. As a result, the company now offers a new line of air and hydraulic cylinders for applications "too hot" for conventional cylinders . . . brakes or clutches, and equipment on drying ovens, heat-treating furnaces, foundry units, and plastic presses.

Because O-rings made of Silastic remain elastic — and maintain a permanent, reliable, tight seal at both high and low temperatures — Carter cylinders now render dependable, long term service over a broader temperature span. *(Cont. Pg. 2)*



FOR LASTING BEAUTY

Eye appeal that lasts. Protection that's built-in. How do you obtain both for metal parts that get hot in service . . . space heater grilles, for example? A heat-stable silicone finish is the answer, according to Heil-Quaker Corporation, Nashville, Tenn.

This company's "Quaker" brand of thin-line home heaters are noted for their trim, stylish appearance. Every cabinet is equipped with exclusive Sun-glo radiants that cast a combination of reflected and circulated warmth through the protective shield grilles. Since these grilles are prominent in the design, their lasting "good looks" is a major requirement.

That's why Heil-Quaker design engineers specify a baked-on gold colored silicone enamel formulated by Midland Industrial Finishes, Waukegan, Ill. This rich decorator color sparks both appearance and sales! And because it's made with Dow Corning silicone resin, the finish retains its "factory fresh" look indefinitely; does not discolor, crack, or craze under heat from the radiants; shows little or no deterioration in severe life tests.

Silicone appliance finishes readily withstand temperatures to 500 F and higher, have excellent color and gloss retention. Available from leading paint formulators in a full range of colors, these coatings have proved ideal for space heaters, incinerators, oven thermostats and many other "hot" products. Other silicone-based finishes are used on food display cases, refrigerators, bathtubs and similar units where a durable, lightweight, and less-costly-than-porcelain finish is desired. **No. 242**

How To Be A Successful Designer

Develop products that exceed customer expectations. Such extra performance creates the customer satisfaction that is so necessary in building brand recognition and preference.

But how do you give your designs that all-important extra edge in performance? Using Dow Corning Silicones is one sure way — particularly if you're concerned with designing consumer products such as home appliances.

Next question: What silicones to use and how to use them to improve appliance performance? You'll find the answers to these questions are outlined and illustrated in the sparkling new Dow Corning booklet, "Extra Edge for Extra Sales." Even if you're not an appliance designer, you'll find a wealth of interesting and useful information in this colorful 8-page bulletin. Be sure to send for your informative copy today. **No. 241**

FOR DATA RELATING TO THESE ARTICLES, CIRCLE REFERENCE NUMBER IN COUPON ON NEXT PAGE
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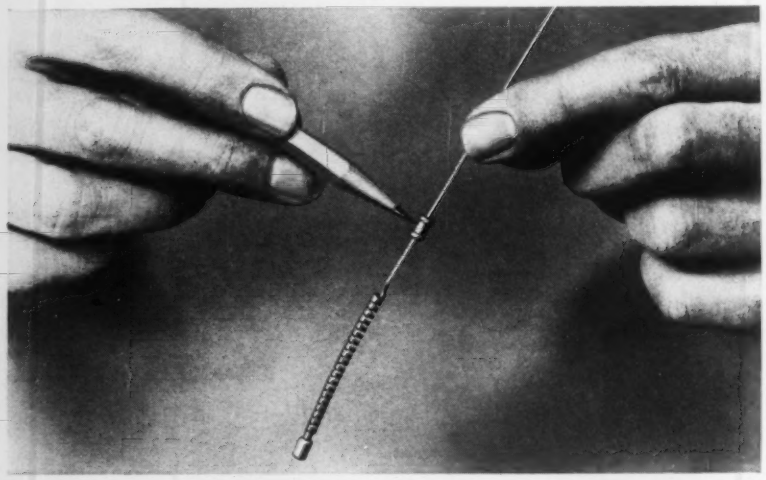
MORE



DAMP OUT INACCURACY

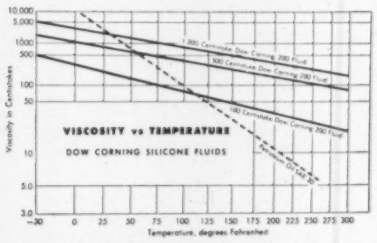
Here's how silicones help damp out unwanted vibration and shock . . . improve performance over wide temperature ranges. Instrumentation engineers at the Rochester Manufacturing Company, Rochester, New York, provided this good example:

RMC produces shock and vibration resistant bimetal thermometers that are accurate within 1% over extremely wide temperature ranges. The company assures this kind of accuracy by double damping . . . coupling the effects of specially designed bearings with the uniform performance of a silicone damping fluid.

Undamped elements subjected to continuous shock or vibration have a tendency to unwind and throw the instrument out of calibration. Damping with silicone fluid protects the thermometer's accuracy, especially in the temperature ranges up to 400 F where a very thin bimetal element is used. The silicone fluid holds the heat-sensing element in place and prevents the shifting which destroys accuracy.

In addition to assuring accurate calibration, silicone fluid damping also improves dial readings. It steadies an otherwise jittery "needle" and makes possible quick, accurate temperature readings even when vibration is severe enough to blur the outline of the thermometer itself.

The following graph shows why Dow Corning silicone fluid provides uniform damping action in this instrumentation application . . . and in numerous sensitive automotive and aircraft devices. *No. 244*



SILASTIC *(Continued)*

Can improved performance widen the use of your product . . . open new markets? If so, it will pay you to investigate the silicone fluids, lubricants, resins, adhesives, dielectrics, rubbers, and other silicone products available from Dow Corning. A personal copy of the new *Engineering Guide to Dow Corning Silicones* is yours for the asking. Circle . . . . . *No. 243*

new literature and technical data on silicones

A new, ready-to-use adhesive for silicone rubber, Silastic 140 Adhesive, requires no catalyst, no premixing. It cures at room temperature to a strong, resilient bond without need of heat or pressure. Retains good bond and rubbery characteristics at temperatures ranging from —70 to 500 F. Typical properties, bond strengths, and other performance data about this new adhesive for silicone rubber are available. *No. 245*

Meet today's electronic needs: Dow Corning Silicones enable electronic equipment and products to meet today's tougher performance requirements . . . make possible new designs. How to achieve miniaturization, better environmental protection, and assure performance on demand is outlined in a new Electronics Engineers' Guide to Silicones. In addition to application illustrations, this guide contains processing information and engineering data . . . leads to the selection of silicones that'll best withstand heat, corona, voltage stress, mechanical stress, chemical attack, moisture, fungus and fire. *No. 246*

A B C's of Defoaming — The literal ABC's to fast antifoam action are compiled for you in a new comprehensive brochure on Dow Corning silicone foam suppressors. This 8-page booklet gets down to cases showing how these versatile antifoam agents are actually reducing maintenance time . . . processing time . . . costs . . . while increasing production capacity . . . efficiency . . . economy. This new manual on foam control in the processing of chemicals, food and drugs, petroleum and asphalt, paper and textiles, as well as in laboratory work and the metalworking industries is available for your files. Circle . . . . *No. 247*

Stator Encapsulation — A manual of procedure-to-follow details how to encapsulate stator windings of random-wound induction motors with Silastic RTV, the Dow Corning silicone rubber that vulcanizes at room temperature. A ten-page, illustrated instruction sheet also outlines the advantages of this silicone protection, and gives specifics about the materials, procedure, details, and typical properties you will want to be familiar with! *No. 248*

Dow Corning Corporation, Dept. 5308, Midland, Michigan

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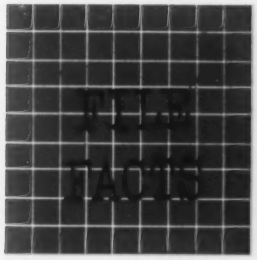

Weldability of Metals Rated by Process[a]

Welding Process →	Arc Welding					Gas Welding (oxyacetylene)
	Shielded Metal Arc	Submerged Arc	Atomic Hydrogen	Inert Gas Tungsten-Arc	Inert Gas Metal-Arc	
FERROUS						
Cast Iron	Common	Seldom	Seldom	Common	Seldom	Rec
Gray Iron	Common	Seldom	Seldom	Common	Seldom	Rec
Low Carbon Steel	Rec	Rec	Common	Common	Common	Rec
Medium Carbon Steel	Rec	Rec	Common	Common	Common	Rec
Low Alloy Steel	Rec	Rec	Common	Common	Common	Common
Stainless Steel						
Austenitic	Rec	Rec	Rec	Rec	Rec	Common
Ferritic	Rec	Common	Common	Common	Common	Common
Martensitic	Rec	Common	Common	Common	Common	Common
Heat Resistant Alloys	Rec	Common	Common	Common	Common	Common
NONFERROUS						
Aluminum[b]	Common	Seldom	Common	Rec	Rec	Common
Copper[b]	Seldom	Seldom	Seldom	Rec	Rec	Common
Gold	Seldom	Seldom	Rec	Rec	Common	Rec
Iridium	Seldom	Seldom	Rec	Rec	Common	Rec
Magnesium[b]	No	No	Seldom	Rec	Common	Seldom
Nickel[b]	Rec	Common	Common	Rec	Rec	Common
Platinum	Seldom	Seldom	Rec	Rec	Common	Rec
Silver	Seldom	Seldom	Rec	Rec	Common	Rec
Titanium[b]	No	No	No	Rec	Rec	Rec

Welding Process →	Resistance Welding		Thermit Welding		Brazing	
	Flash	Spot	Pressure	Nonpressure	Furnace	Torch
FERROUS						
Cast Iron	Seldom	No	Common	Common	Seldom	Rec
Gray Iron	Seldom	No	Common	Common	Seldom	Rec
Low Carbon Steel	Rec	Rec	Common	Common	Rec	Common
Medium Carbon Steel	Rec	Rec	Common	Common	Rec	Common
Low Alloy Steel	Rec	Rec	Common	Common	Common	Seldom
Stainless Steel						
Austenitic	Rec	Rec	Seldom	Seldom	Rec	Common
Ferritic	Common	Common	Seldom	Seldom	Common	Common
Martensitic	Common	Common	Seldom	Seldom	Common	Common
Heat Resistant Alloys	Common	Common	Seldom	Seldom	Seldom	Seldom
NONFERROUS						
Aluminum[b]	Common	Rec	No	No	Rec	Rec
Copper[b]	Common	Common	Seldom	Seldom	Common	Rec
Gold	Common	Common	Seldom	Seldom	Common	Rec
Iridium	Common	Common	Seldom	Seldom	Common	Rec
Magnesium[b]	Seldom	Common	No	No	Seldom	Seldom
Nickel[b]	Common	Rec	No	No	Rec	Rec
Platinum	Common	Common	Seldom	Seldom	Common	Rec
Silver	Common	Seldom	Seldom	Seldom	Common	Rec
Titanium[b]	Common	Common	No	No	Common	Common

[a]Rec = recommended; easily accomplished with excellent results. Common = commonly and widely used, though some care may be necessary. Seldom = can be done with more or less difficulty, but not common for one reason or another. No = not used; impossible or highly specialized case if ever used.
[b]And its alloys.

Based on information supplied by A. O. Smith Welding Institute.

Tough Target

Fire globes of tough Tenite Butyrate plastic cut replacement costs for New York City

Here's a good example of how a switch to plastic can improve product performance.

In New York City, orange-colored light globes mounted on nearby poles are used to call attention to the location of fire alarm boxes. However, over the years, vandal breakage of the glass globes had become a growing problem. Four years ago, two of the boroughs found an answer—they switched to globes of Tenite Butyrate plastic. Since then, each broken globe has been replaced with one made of Butyrate. Result: the replacement rate has been cut by as much as 60%. And even this improvement will be bettered in another year when the whole system will have been converted to Butyrate globes.

As in so many other applications, Tenite Butyrate supplied a superior combination of the properties needed...high resistance to impact, weather durability, good moldability and excellent light transmission. Of importance, too, the Tenite Color Laboratory developed a color formulation that duplicated the orange hue of the original glass globes.

Perhaps your company has an outdoor material problem that could be solved by a switch to Tenite Butyrate.

Why not investigate this tough, durable plastic? For information, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENN.

TENITE®
BUTYRATE
an Eastman plastic

Fire globes molded of Tenite Butyrate by A. L. Hyde Co., Grenloch, N. J., for The Welsbach Corporation, Philadelphia 2, Pa., which does street lighting maintenance for the City of New York. Commenting on the considerable reduction in replacements since switching to Butyrate, Welsbach's New York City manager says, *"Butyrate's resistance to shock is so great that no replacement is necessary when the globes are pierced by BB shot or even small bullets. They resist damage from small stones, and even large rocks will only tear the Butyrate, leaving the globe in serviceable condition."*

MATERIALS AT WORK

...AT A GLANCE

Titanium is said to be the key to a new portable atomic weapon. The weapon, a lightweight recoilless gun capable of firing atomic shells, consists of three thread-jointed titanium parts. In addition to weight savings (weight is about one-tenth that of conventional recoilless guns), titanium was selected because it 1) provides high strength (heat treated yield strength is over 200,000 psi); 2) has an excellent strength-to-density ratio; 3) offers excellent resistance to corrosion; and 4) poses no operating problems at temperatures ranging from —65 to 125 F.

Source: Titanium Metals Corp. of America; designed by Frankford Arsenal.

Heat sensitive paper is now recording performances of missiles and satellites. The new paper, which replaces the previously used pressure sensitive type, is said to produce faster, more legible permanent tracings of oscillographic signals. The paper contains two layers: a base consisting of a combination of rubber latex and carbon black, and a top coating of a low density material high in air content. When heat is applied, the top coating becomes transparent and allows the black base to show through.

Source: B.F. Goodrich Chemical Co.

The world's first home movie sound camera uses aluminum die castings for several major components. The camera, which weighs only 4½ lb, uses about 2½ lb of aluminum for four of the largest and most intricate parts. The companion projector uses about 2¾ lb of aluminum. Reasons given for the selection of aluminum: light weight, ease of casting, and ability to obtain a satin finish without additional plating.

Source: Aluminum Co. of America; camera and projector manufactured by Fairchild Camera & Instrument Corp.

Use of conductive diallyl phthalate for elements of potentiometers has eliminated several problems in the design of control systems for missiles, rockets, and other equipment. The precision potentiometers consist essentially of a ring of carbon-filled diallyl phthalate molded onto a diallyl phthalate insulating base. The conductive ring replaces previously used wound wire, and the molding operation eliminates the use of varnishes and cements. The new units are said to have almost infinite life.

Source: Chemicals & Plastics Div., Food Machinery & Chemical Corp.; potentiometers produced by New England Instrument Co.

ABS resins are used in the first portable plastics auto-home air cooler. The unit, which weighs only 8 lb (or 17 lb less than any other portable auto-home cooler of comparable size), uses ABS (acrylonitrile-butadiene-styrene) for the housing and circulating pump. The unit can either be plugged into an auto's cigarette lighter or operated through a small transformer at home. Primary advantages of ABS are strength, durability, light weight and a glossy surface that resists chipping, marring, scratching or peeling.

Source: Marbon Chemical Div., Borg-Warner Corp.; cooler manufactured by G & B Mfg. Co.

For more information, turn to Reader Service card, circle No. 416

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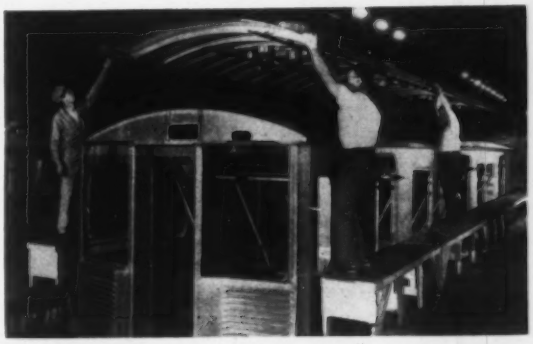
Subway Converts to Stainless Cars to Cut Cost

The first few cars of what will soon be an "all-stainless" fleet of 270 are now riding the rails of Philadelphia's old Market-Frankford subway-elevated line.

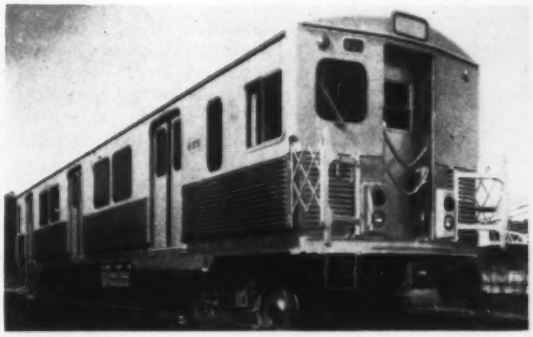
Use of stainless, with its high strength-weight ratio, has kept the weight of the new cars to 52,000 lb—about 6000 lb less than the weight estimated for conventional steel construction. The result, according to Philadelphia Transportation Co., will be about a 12% saving in power consumption, as well as greater operating speed.

In addition, the fact that the stainless will not need painting is expected to cut maintenance cost by $428 per year per car.

Most of the stainless used is type 201 or 202. The subway cars may represent the largest single use of these low nickel alloys.

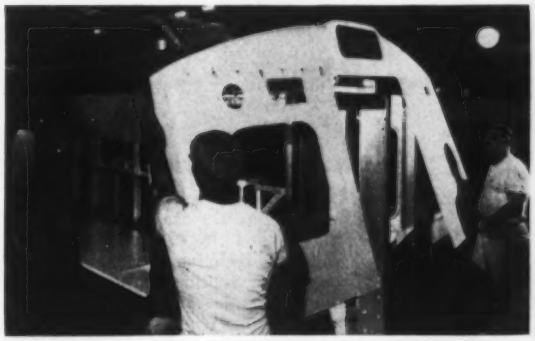


Design *of car is based on aircraft concepts. Roof and floor serve as chord members and sides carry shear. Carefully controlled resistance spot welding is used throughout to produce a sound, integral unit.*



New car *is 55 ft long, seats 56 passengers. Most structural members are 201 and 202 stainless but end underframes are NES 65 high strength, low alloy steel. Flooring is plywood faced on both sides with aluminum.*

Interior trim *includes moldings of type 430 stainless steel, seat frames of anodized aluminum, and paneling of melamine plastic laminated to plywood. Seat covers are vinyl-coated duck.*



Plastics, too, *are used to a limited extent. Upper front end of car is fiberglass-reinforced polyester molded in one piece in gray color to match metal.*

Two production lines *at Budd Co.'s Red Lion plant in Philadelphia are expected to be turning out two complete cars a day by sometime next month.*

the ACCURATE WAY to test MICRO and MACRO hardness

Wilson TUKON hardness tester

•Wilson TUKON testers make and measure extremely shallow indentations. They are used, for example, by manufacturers of watches, hairsprings, needles and jewels. In laboratories, TUKON instruments test individual crystals or microscopic particles. On any job, they provide these important advantages:

Accuracy—Precision-built TUKON testers give consistently correct results. Loads are applied without friction or impact—Bausch & Lomb optical equipment is standard—vibration is closely controlled.

Long life—Simple design, rugged construction make TUKON testers as durable as a machine tool.

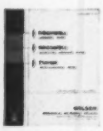
Easy operation—Even an unskilled operator can get perfect readings after a short training period.

Supplied complete—Special accessories for various sizes and shapes.

A complete line of Wilson Rockwell instruments is available, including semi and fully automatic models.

Wilson "Brale" Diamond Penetrators Each diamond is cut to an exact shape. A comparator check and microscopic inspection of each diamond assure perfect readings every time.

Write for details—Ask for Catalog RT-58. It gives complete information on the Superficial tester as well as on the full line of Wilson Rockwell hardness testers.



WILSON "ROCKWELL" HARDNESS TESTERS

ACCO

Wilson Mechanical Instrument Division
American Chain & Cable Company, Inc.
230-E Park Avenue, New York 17, New York

For more information, turn to Reader Service card, circle No. 337

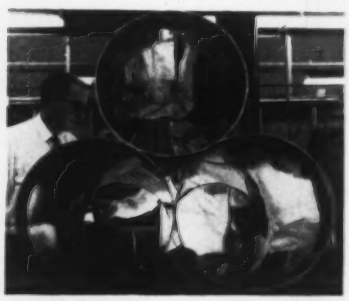
Extruded Nylon Collet Replaces Tool Steel

The switch from hardened tool steel to extruded nylon has resulted in reduced costs, increased life and greater efficiency of collets used to hold fragile ceramic dielectrics in a processing operation.

The switch was specified primarily to reduce breakage in one stage of the automated process. In that operation, the collets are used to feed, grip and discharge the fragile, ⅛-in. dia tubes at high speeds. With the hardened tool steel collets previously used, almost 8% of the tubes were broken.

The new collets, machined from extruded nylon rod, reduced breakage by about 80%. And although materials costs are several times higher, the total cost of the nylon collets is about one-third that of the steel collets. Here's why: 1) standard metalworking equipment forms the nylon about twice as fast as the best machining tool steels; 2) there is considerably less waste; and 3) there are no time-consuming hardening operations.

Another advantage of nylon over steel: when the steel collets wore and became too large (due to the



Rocket chambers—Shown above are some test rocket chambers now being made by a special "strip-winding" technique. The technique consists of winding "paper-thin steel alloys of great strength" around a mandrel until the desired thickness is created, and then tackwelding and spotwelding. According to Ryan Aeronautical Co., the cylinders are capable of withstanding a static tension stress of 350,000 psi.

HAYNES ALLOYS

RESEARCH REPORTS

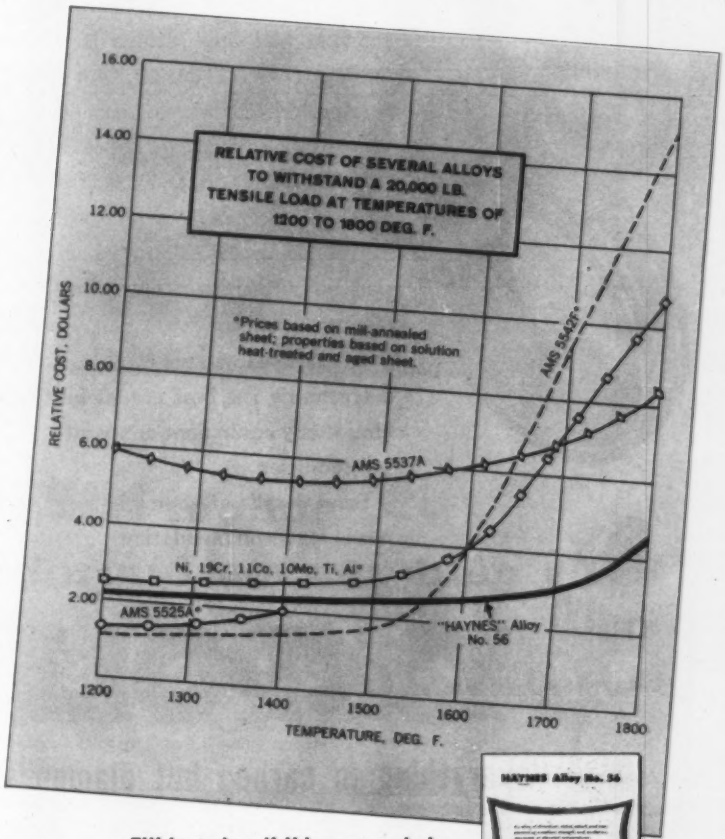
New High-Temperature Alloy Improves Cost-To-Strength Ratio

Excellent strength and oxidation resistance in the 1200 to 2000 deg. F. range are among the features of HAYNES Alloy No. 56—a new high-temperature alloy developed by Haynes Stellite Company.

A sampling of its cost advantages at a given tensile load, compared with other high-temperature alloys in the graph at the right, is well worth your study.

Alloy No. 56 can be readily hot-worked and formed. It is easy to heat treat. It comes in the form of sheet, plate, bar, wire, and coated welding electrodes, and can be furnished as sand-, investment-, and resin shell-mold castings. The coupon below will bring you a wealth of technical data.

The new iron-base alloy contains nickel, cobalt, chromium, and molybdenum. It has high strength at temperatures up to 1500 deg. F and maintains useful strength at temperatures as high as 2000 deg. F.



Fill in and mail this coupon today

Haynes Stellite Company, Dept. 31
270 Park Avenue, New York 17, N.Y.

Please mail me the free, 16-page properties-data booklet on the new HAYNES Alloy No. 56.

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SEAL RING PROBLEMS *Solved!*

As with most carbon, graphite or molded metal powder products made by Stackpole, recommendation of suitable grades for mechanical seal applications is a matter of careful "custom" engineering. That's where over 50 years of specialized experience in this field really counts. Dozens of Stackpole standard grades are subject to almost infinite variation for either rings or mating members. And Stackpole seal engineers know their way around in determining the best grades for almost any equipment or operating condition.

Send details of your seal ring needs for recommendation.

STACKPOLE

"everything in carbon but diamonds"

LOW-FRICTION Clutch Rings

Stackpole carbon rings frequently replace ball thrust bearings with appreciable cost savings.

STACKPOLE CARBON CO.
St. Marys, Pa.

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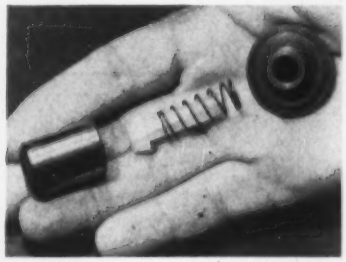


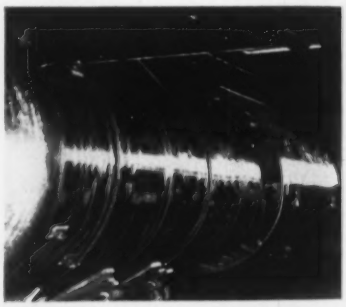
***Nylon collet** operates under spring pressure inside steel collar.*

absence of lubricants which would contaminate the ceramic parts) they had to be scrapped. The nylon collets, on the other hand, can be re-bored and used for the next larger size of ceramic tube.

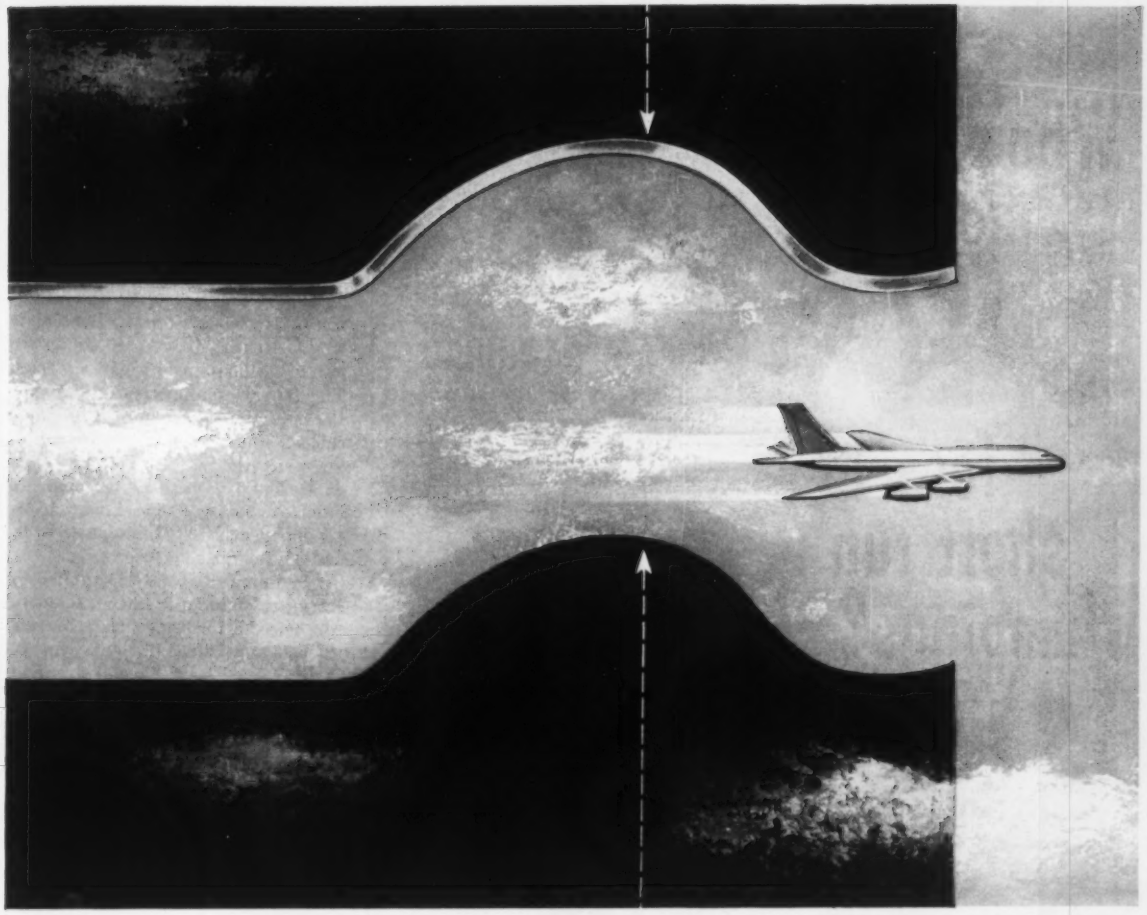
Aluminum Cuts Weight of Liquid Oxygen Tanks

By specifying aluminum for the carriers on six of its new liquid oxygen semitrailers, National Cylinder Gas Div., Chemetron Corp., has been able to increase carrying capacity of each trailer by 40,000 cu ft while reducing overall weight by about 9000 lb.

The carriers are used to store, transport and transfer liquid oxygen and nitrogen at temperatures



Aluminum tanks are used in . . . liquid oxygen semitrailer.



Want to save with plastic tools and dies?

Your EPON® RESIN tooling formulator can help you

Tools and dies made of tough but easy-to-handle Epon resin can save you up to two thirds in time, one third in cost! Your tooling resin formulator will show you how Epon resin formulations are saving time and money—*right now*—in applications such as:

High-temperature tooling: Metal-forming stretch dies that can operate at temperatures over 400° F.

Heated tools: Matched dies, with integral heating units, may be made with Epon resin formulations for rapid heat-curing of laminated plastic parts.

Long-lasting metal-forming tools: Castings made of formulated Epon resin, mounted in a crank press, showed no permanent deformation after 28,000 compression-shock cycles.

For tool and die applications, Epon resin formulations offer you the following important advantages:

Excellent tolerance control: Little machining and handwork are required to finish Epon resin tools because of the material's excellent dimensional stability and lack of shrinkage.

Outstanding strength: Jigs and fixtures with thin cross sections can be built from Epon resin-based formulations reinforced with glass cloth. The resulting laminate has high flexural strength and excellent dimensional stability.

Easy modification: Tools and fixtures made from Epon resins may be quickly and easily modified to incorporate design changes.

CONTACT YOUR TOOLING RESIN FORMULATOR

The combination of resin formulator's skill and application knowledge, backed by Shell Chemical's research and resin experience, has solved many important tooling problems for industry. For a list of experienced tooling resin formulators and additional technical information, write to:

SHELL CHEMICAL COMPANY

PLASTICS AND RESINS DIVISION

110 WEST 51ST STREET, NEW YORK 20, NEW YORK

Central District	East Central District	Eastern District	Western District
6054 West Touhy Avenue	20575 Center Ridge Road	42-76 Main Street	10642 Downey Avenue
Chicago 48, Illinois	Cleveland 16, Ohio	Flushing 55, New York	Downey, California

IN CANADA: Chemical Division, Shell Oil Company of Canada, Limited, Toronto

SHELL

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"Who's best at meeting SPECS for short run stampings?"

FEDERAL

SHORT RUN STAMPINGS

3 PLANTS To Serve You Better

Freddy Federal says: "Every stamping job you give us, big or small, tough or easy, gets Federal's continuous step-by-step inspection. Highly skilled tool makers use exclusive Federal techniques to make dies for your stampings, with an accuracy equal or superior to ordinary methods, at cost savings up to 80%. Federal has the special equipment and experience needed to meet your particular stamping tolerance and design requirements. Added to this is the personal interest of Federal craftsmen who take great pride in having their work please you. Try us today by sending your part or print for a prompt air-mail quotation. If time is short, just ask for a reply by phone or wire. Let Federal stampings meet your specs!"

Write for illustrated Catalog No. 301 with money-saving stamping design tips.

FEDERAL TOOL & MFG. CO.
3652 Alabama Avenue
Minneapolis 16, Minnesota

FEDERAL SHORT RUN STAMPING, INC.
952 Lyell Avenue
Rochester 6, New York

FEDERAL STAMPING COMPANY
7352 Atoll Avenue
No. Hollywood, California

For more information, turn to Reader Service card, circle No. 375

slightly under their boiling points (–297 F and –320 F, respectively).

Each carrier uses about 10,000 lb of 5083 aluminum plate and extrusions. It consists of two concentric tanks separated by 6 in. of an expanded silica insulating material. The inner tank is suspended inside the outer by a system of adjustable cables. Four aluminum baffle plates serve as thermal conductors to reduce liquid stratification and to eliminate splash. Approximate overall dimensions: 32 ft long, 8 ft wide, and 11 ft high.

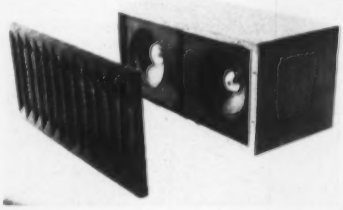
Aluminum alloy 5083, supplied by Kaiser Aluminum & Chemical Corp., was selected for the carriers because it has high strength and can be easily welded by the metal arc-inert gas method. In addition, it has the approval of the ASME for use in welded pressure vessels.

Acrylic Grill Cloth Improves Hi-Fi Units

Woven acrylic fabric, vacuum formed into a permanently stiffened three-dimensional pattern, is now being used for grill cloths on new high fidelity and stereophonic speaker units.

According to Audax, Inc., a division of Rek-O-Kut Co., Inc., the acrylic fabric is functional as well as decorative: it provides an "exceptionally well balanced range of frequency responses, as compared to standard grill cloths." The response is attributed to the forming operation which increases the material's porosity.

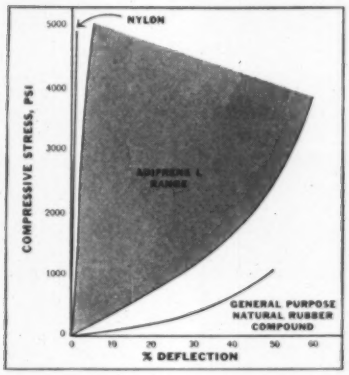
According to Union Carbide Chemicals Co., acrylic (Dynel) was selected because the woven or knitted fabric is easily molded, embossed or stiffened.



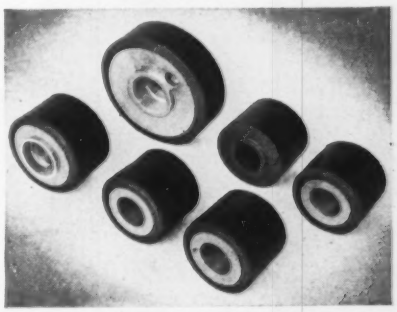
***Three dimensional cloth** is both decorative, functional.*

ADIPRENE®

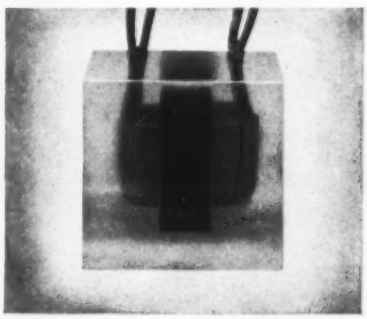
new Du Pont liquid urethane elastomer



CARRIES A HEAVY LOAD An outstanding attribute of this new Du Pont synthetic rubber is its combination of toughness, high load-carrying ability and resilience. Load-bearing capacities of hard ADIPRENE L compounds far excel those of general purpose synthetic rubbers.



RESISTS ABRASION Both in the laboratory and in actual service, ADIPRENE L has demonstrated its ability to resist wear. On industrial wheels it has outlasted natural rubber as much as 10 times . . . has more than doubled service in pump impellers handling abrasive slurries.



NOT BRITTLE AT "EIGHTY BELOW" ADIPRENE L vulcanizates maintain their resilience at –20° F. . . . and do not become brittle at temperatures as low as –80° F. They exhibit outstanding resistance to thermal shock, and will operate at intermittent temperatures as high as 250° F.

OTHER PROPERTIES Products made from ADIPRENE L are available in various hardnesses from 10 to 99 Shore A (78 Shore D). They resist the action of lubricating oils, greases, weak acids, alkalies, as well as oxygen, ozone and radiation. Suggested uses for ADIPRENE L include industrial rolls, motor mounts, seals, potting compounds, solid tires, striker plates, wear-resistant linings and coverings. Write for booklet on properties and applications of this new material. E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Dept. MDE-8, Wilmington 98, Del.

DU PONT SYNTHETIC RUBBER
NEOPRENE HYPALON® VITON® ADIPRENE®
Better Things for Better Living . . . through Chemistry

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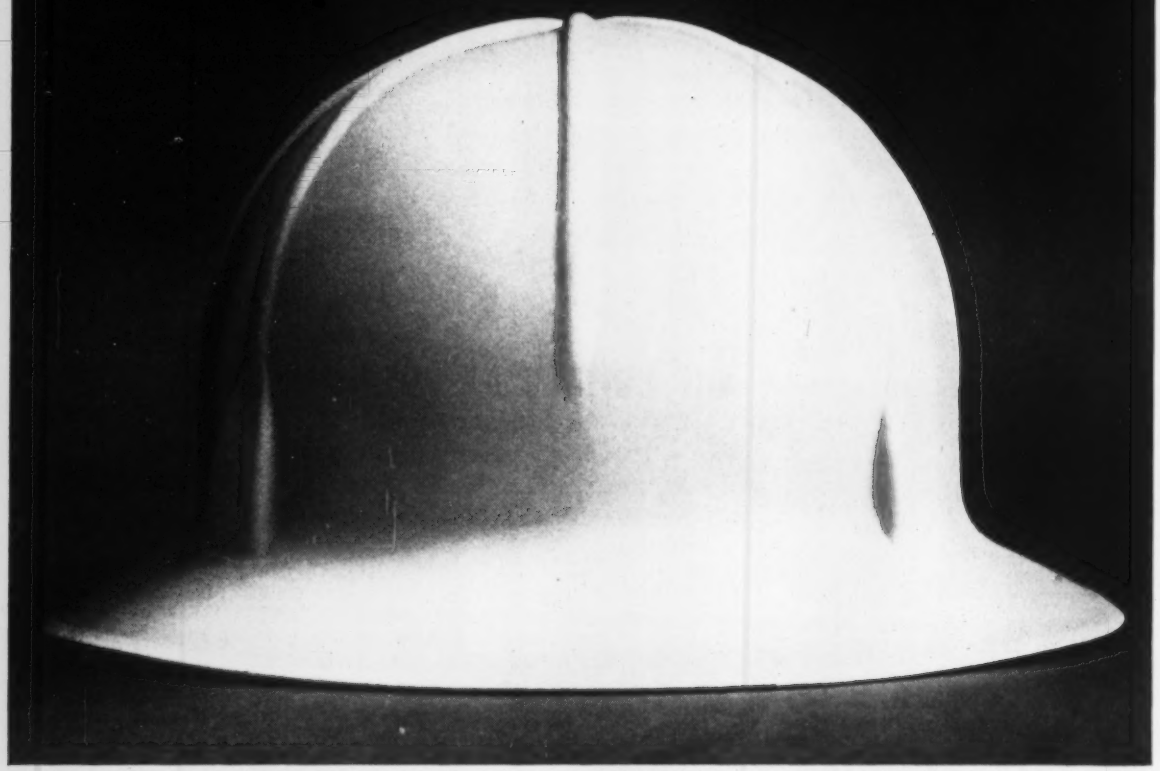
THINK POLYESTER RESINS! THINK **LAMINAC®** THE PIONEER POLYESTER!

■ Ease of fabrication in unusual shapes ■ Corrosion-resistance ■ High strength with low weight ■ Excellent electrical properties ■ Low tooling costs ■ Below are just a few of the 22 standard formulations of Laminac® Polyester Resins. Reinforced plastics with Laminac have been replacing wood and steel in countless areas since 1942 – when American Cyanamid pioneered the reinforced plastics field. Whatever *your* needs, there is a formulation of versatile Laminac specially compounded to solve your problems. For more information, write us today.

FITS ANY ENGINEER'S SPECIFICATIONS



LAMINAC 4107. Outstanding chemical-resistant resin; high reactivity; suitable for compression molding; especially suited for chemical tanks, exhaust systems and other equipment.

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LAMINAC 4152. An outstanding resin for spray gun applications; rapid cure; unexcelled strength properties in laminates with chopped glass fibers; for use in boats, swimming pools, other large structures.

LAMINAC 4128. Highly reactive, heat-resistant resin for hand lay-up or compression molding; exceptional strength in laminates; qualified for military specification MIL-R-7575A; ideal for glass preform binders; for ducts, fuel tanks, storage tanks, aircraft parts.

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PLASTICS AND RESINS DIVISION

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TECHNICAL LITERATURE

(cont'd from p 49)

Books

Corrosion and Oxidation of Metals. *Ulick R. Evans. St. Martin's Press Inc., New York. 1960. Cloth, 6 by 9 in., 1100 pp. Price $25*

Reviewed by Herman S. Preiser*

This book presents in clear, simple language, often philosophical in tone, an authoritative compendium of the science of corrosion phenomena and means for its control.

Dr. U. R. Evans, at the peak of his eminence, compresses 50 years of his theoretical studies and practical experience in the general field of corrosion into an informative and important reference work. Accordingly, this volume should appeal to a broad class of scientists, engineers and technical personnel directly or indirectly concerned with the behavior and use of metals in various environments.

Emphasizes personal views held by author

The book emphasizes the personal views held by Dr. Evans regarding the mechanisms of various corrosion phenomena, adequately supported by experimental evidence derived in his laboratory and confirmed by outside workers. Where differences of viewpoint exist among other investigators, these other schools of thought are included for completeness and allowed to stand on their own merits.

Much care has gone into the selection of the subjects covered, each chapter being a complete and separate essay unto itself with a synopsis to indicate material covered and how each chapter interrelates with the others. The major references are listed at the end of each paragraph for the convenience of the reader who may be interested in any individual aspect of the subject at a given time.

Contents divided into qualitative, quantitative sections

The contents of the book are divided into a qualitative and a quantitative section. The qualitative section is of interest to those who want an understanding of corrosion reactions and means for their control. The quantitative section is for the experimenter and serious scientific worker who desires specific information on methodology and techniques for measurement of corrosion reactions.

Two appendices, one on general chemistry and one on physical chemistry and electrochemistry, are thoughtfully added to provide background information for those individuals who are active or interested in corrosion work, but who have not had formalized courses of instruction in these primary subjects.

Subject matter is complete

The subject matter is essentially complete and comprehensive including the broad categories of oxidation; electrochemical corrosion; atmospheric corrosion; corrosion by cojoint action such as fatigue and impingement attack; protective measures by inhibitors and paints; cathodic protection and specific applications to buried structures, boilers and condensers; bimetallic contacts; and crevice corrosion. Laboratory methods for velocity measurement, testing of film growth and wet corrosion are also included, with a final chapter on statistical considerations for interpreting nonreproducible data.

The book is not intended as a textbook for students, a handbook for engineers, or a scholarly work for theoreticians, but rather it is intended as an up-to-date reference work for background information and general guidance to interested persons.

*Consulting corrosion engineer for the Navy's Bureau of Ships.

Distortion in Tool Steels. *B. S. Lement. American Society for Metals, Novelty, Ohio. 1960. Cloth, 173 pp. Price $10*

Discusses dimensional changes in tool steels during and after heat treatment. Problems involved in producing tool steel parts with tolerances of less than one ten-thousandth of an inch are treated in detail. Many illustrations, tables and graphs, and an index are included.

Glass: Its Industrial Applications. *C. J. Phillips. Reinhold Publishing Corp., New York. 1960. Cloth, 6 by 9 in., 260 pp. Price $6.95*

Covers the manufacture, physical and chemical properties, and particularly, the ap-

BORIDES
for modern industry

Leadership in high temperature technology, symbolized by the NORTON FIREBIRD, has made possible the production of the borides of chromium, titanium and zirconium in tonnage quantities.

In the METAL INDUSTRY, aluminum manufacturers utilize the low electrical resistivity and high resistance to attack by aluminum and cryolite that borides of titanium and zirconium provide. Borides are ideal boron sources for super alloys and nuclear steels . . . ROCKET ENGINE manufacturers take advantage of the superior resistance to erosion and corrosion at high temperatures that zirconium boride offers.

NORTON borides, because of their unusual properties, are being examined closely at Research and Development level as shapes and coatings for many applications.

In addition, borides of calcium, molybdenum, and vanadium are available on a limited basis for evaluation. If you have a specific requirement, let's hear about it. Write NORTON COMPANY, Electro-Chemical Division, 347 New Bond St., Worcester 6, Mass.

Send for booklet on borides and other Norton Electro-Chemicals.

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ELECTRO-CHEMICALS

GIFTS OF THE FIREBIRD: compounds of silicon zirconium • boron • aluminum • magnesium titanium • chromium • including many borides carbides • nitrides • oxides

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Making better products... to make your products better

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may be your ANSWER

If you are faced with a tough problem involving high temperature, corrosion, abrasion, chemical action or electronic insulation, McDanel alumina ceramics may be your answer.

McDanel custom produced alumina ceramics are being applied to a wide variety of difficult applications with excellent success.

Send a description of the problem and a sketch of the parts. McDanel engineers are eager to work with you and give you the benefit of their experience and craftsmanship.

Write for Physical Properties Bulletin today.

McDANEL Industrial CERAMICS

McDANEL
REFRACTORY PORCELAIN COMPANY
BEAVER FALLS · PENNSYLVANIA

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plications of all types of glass. The book reflects all the recent advances in the field and includes new information on such subjects as glass bead reflectorization and the "float glass" process for making flat glass. Included is a geographical index of American and Canadian glass factories.

Metal Industry and Directory: 1960. *Iliffe & Sons Ltd., London, England. 1960. Paper, 6 by 9 in., 584 pp. Price $4.50*

Corrosion Data Survey. *Compiled by G. A. Nelson. Shell Development Co., Div. of Shell Oil Co., Emeryville, Calif. 1960. Cloth, 8½ by 11 in., 152 pp. Price $50*

Series of 50,000 charts with about 500,000 reference points that list process streams ranging from abietic acid to zirconium nitrate. Tells at a glance the best type of material to use for a particular stream in concentrations to 100% at temperatures from 75 to 800 F for corrosion rates of less than 0.002 in. per year to over 0.05 in. per year. The book illustrates in a general manner the behavior of about 1500 corrosive environments when in contact with approximately 50 constructional materials.

Direct Conversion of Heat to Electricity. *Edited by J. Kaye and J. A. Welsh. John Wiley & Sons, Inc., New York. 1960. Cloth, 6 by 9 in., 367 pp. Price $8.75*

Discusses thermoelectric energy conversion (thermocouple), thermionic energy conversion (the vacuum tube and the gaseous tube), magneto hydrodynamics conversion (separating the positive and negative charges in a gas), and fuel cells (the separation of positive and negative charges during a chemical reaction).

Reports

Welding nuclear piping. WELDING FERROUS MATERIALS FOR NUCLEAR POWER PIPING. *American Welding Society, 33 W. 39th St., New York 18. 1959. 14 pp. Price $1.50 (No. D10.5-59)*

Properties of cast steel INVESTIGATION OF SOLIDIFICATION OF HIGH-STRENGTH STEEL CASTINGS UNDER SIMULATED PRODUCTION CONDITIONS. *Massachusetts Inst. of Technology. July '58. 58 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price $1.50 (PB 151753)*

Discusses effects of solidification variables on structure and properties of high strength cast steels. Tensile and yield strengths were essentially constant, but large variations in elongation and reduction of area properties were observed depending on solidification conditions.

Effect of radiation on ferrites EFFECTS OF NUCLEAR IRRADIATION UPON THE MICROWAVE PROPERTIES OF CERTAIN FERRITES. *N. G. Sakiotis, E. I. Salkovitz and A. I. Schindler, Naval Research Laboratory. June '59. 10 pp. Available from Office of Technical Services, Dept. of Commerce, Washington 25, D. C. Price 50¢ (PB 151691)*

Nuclear irradiation can change Faraday rotation and insertion loss in a wide variety of ferrites.

Ferrous metallurgy FERROUS METALLURGY LABORATORY MANUAL. *J. S. Umowski. American Technical Society, Chicago. 1960. 90 pp. Price $2.25*

Gives information on physical testing, physical examination of specimens, and heat treatment of ferrous alloys.

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Annealing: Its Uses with Alloy Steels

Broadly speaking, the primary purpose of annealing is to soften steel and make it more workable. Annealing, as applied to alloy steels, may be defined as a process that heats above, and furnace-cools through, the critical range at a controlled, specified rate of speed; or that heats to a point within, and furnace-cools to a point below, the critical range. In either case, the choice depends upon the structure and maximum hardness desired.

The first method produces a lamellar pearlitic structure, while the second creates a spheroidized condition. These will be discussed separately in the following paragraphs:

(1) *Lamellar pearlitic structure.* It should be mentioned at once that this structure can be obtained both as described above and by a modified method known as isothermal annealing. In the isothermal process, the steel is heated above the critical temperature (austenitized), then transformed at a predetermined temperature, which depends upon the analysis. This operation requires two furnaces or salt baths —one for austenitizing, one for transformation.

Lamellar pearlitic structures are generally associated with machinability in carbon ranges from 0.20 to 0.60 pct, provided the hardness does not exceed the optimum maximum Brinell numeral. This is especially true where critical tooling is involved. It is a very versatile structure, as it gives best results in such operations as broaching, tapping, threading, deep drilling, boring, milling, and tooling as applied on single- and multiple-spindle bar automatic machines.

(2) *Spheroidized structure.* There are two general fields of use for this type of structure when alloy steels are employed. In the low and medium carbon ranges, spheroidization is necessary for cold-shaping operations, such as heading, extruding, drawing. In the higher carbon ranges (over 0.60 pct), it is mandatory where machining is involved, because it tends to lower the hardness of the steel.

If you want more details about these and other uses of annealing, and the results to be expected, by all means consult with our technical staff. And when you need alloy steels, Bethlehem can offer the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
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BETHLEHEM STEEL

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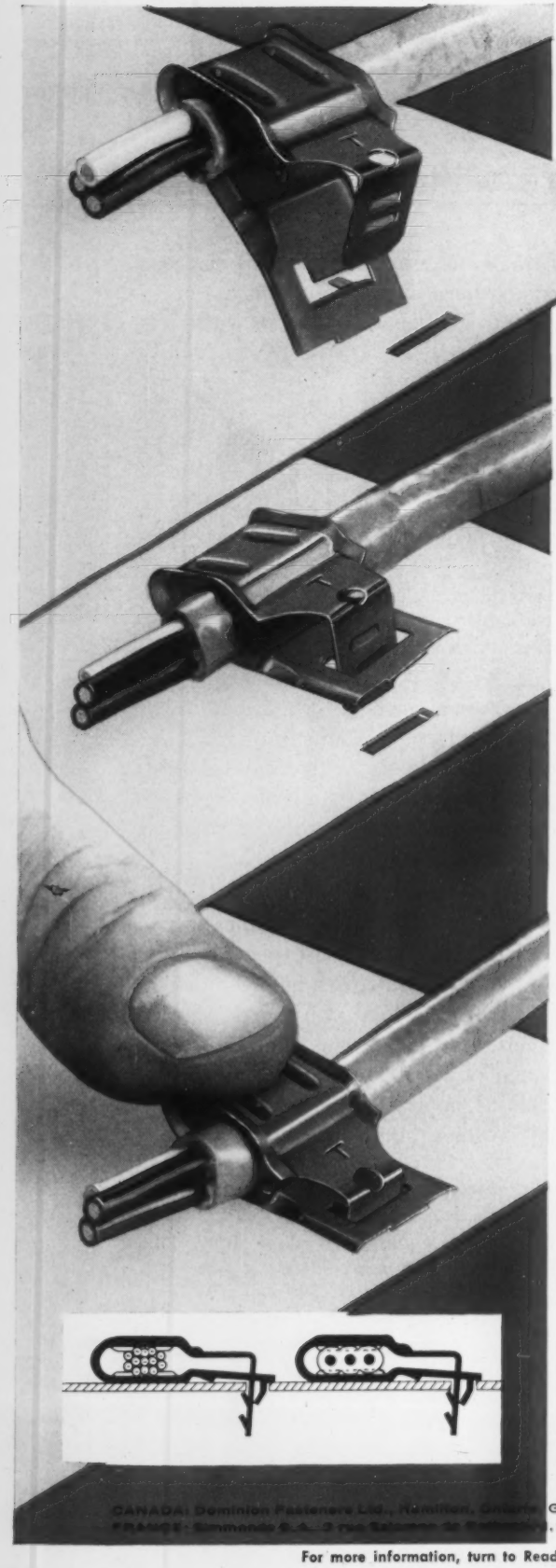

Engineered by Tinnerman...

NEW SPEED CLIP® ANCHORS WIRES, CABLES, TUBING, RELIEVES STRAIN, SIMPLIFIES ASSEMBLY

Made specifically to attach cables, wires, harness, or tubing firmly to panels, this newest Tinnerman SPEED CLIP is readily snapped into place in only 3 simple steps. Prelatch it on the conductor or tubing, insert SPEED CLIP in panel hole, then push home to lock. Assembly costs are reduced because assembly time is cut to the minimum.

Tinnerman SPEED CLIPS also serve as trouble-free strain-relief clamps—they are used extensively on appliances for attaching 3-wire round or horizontal section rib cord, and easily withstand the 35-pound pull test requirements. Double latch permits pre-assembly and accurate retention of SPEED CLIPS to wire or harness before panel assembly for further savings in assembly time. Double-rib retainers grip tightly on round or rectangular cords from .175" round to .306 x .515" rectangle. Important, too, SPEED CLIPS can easily be removed from the mounting side.

Ask your Tinnerman sales representative for samples and prices. He's listed under "Fasteners" in most Yellow Pages. Or write to:

TINNERMAN PRODUCTS, INC.
Dept. 12 • P. O. Box 6688 • Cleveland 1, Ohio

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Speed Nuts®

FASTEST THING IN FASTENINGS®

CANADA: Dominion Fasteners Ltd., Hamilton, Ontario. GREAT BRITAIN: Simmonds Aerocessories Ltd., Treforest, Wales. FRANCE: Simmonds S.A., 2 rue Salomon de Rothschild, Suresnes (Seine). GERMANY: Mecano-Bundy GmbH, Heidelberg.

For more information, turn to Reader Service card, circle No. 399

(cont'd from p 18)

What's new IN MATERIALS

Pyrolitic Graphite Made in Large Pieces

General Electric Research Laboratory, Schenectady, N. Y. has produced what may be the world's largest piece of pyrolitic graphite, according to Dr. Guy Suits, vice president and director of research. The rectangular piece measures 17 by 31 by ⅛ in. thick

Grown by new method

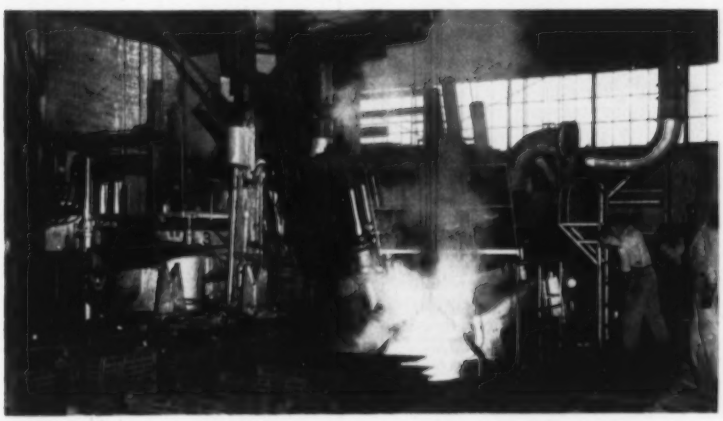
The large graphite piece was grown by a new method in which a heated piece of commercial graphite is placed in a stream of hydrocarbon gas (e.g., methane). The carbon in the gas is deposited on the surface of the original sample, while the hydrogen passes off. As the new material grows, crystals of graphite, composed of carbon atoms, form with their flat planes parallel to the existing surface. An almost completely homogeneous structure builds up, consisting of close-packed columns of graphite crystals. These crystals are joined to each other, along the flat planes, by strong bonds; there are only weak bonds between layers.

A production method for growing pyrolitic graphite is now under development.

Properties

Pyrolitic graphite has recently aroused wide interest because of its ability to withstand extremely high temperatures. It is also stronger and more resistant to oxidation than ordinary graphite.

The material is hard, dense, and silvery-gray, slightly heavier than ordinary graphite. Above 3000 F it is said to have a higher strength-to-weight ratio than any high temperature material now being considered for practical use. Above 5000 F it has a tensile strength of



Alloy steel castings—The picture above shows workmen pouring a heat of U. S. Steel's T-1 constructional alloy steel into a bull ladle at Alloy Steel & Metals Co., 1848 E. 55th St., Los Angeles. The molten metal will later be poured into molds to produce castings. Alloy Steel & Metals is the first foundry licensed by U. S. Steel to produce T-1 steel castings. The castings are expected to be used for crankshafts, sprockets, buckets, blades, wheels, gears, valves and other parts used in heavy construction equipment, trucks, mining machinery and tractors. Cast forms of the steel are said to have the basic mechanical properties of T-1 mill products. KEY NO. 615

DALIC SELECTIVE PLATING for ELECTRONIC COMPONENTS

Plating circuit contacts without dismantling electronic components.

Quick Accurate Way to Plate:

- Semi-Conductors.
- Flexible Circuits.
- On site field repair of Electronic Computer Contacts.

Speeds Production in:

- Automatic plating of Transistor Tabs.
- Gold-plating on Aluminum.
- No-flux soldering on Aluminum and Stainless Steel.

Plate selected areas rapidly without disassembling components. Dalic Process accurately controls thickness of deposits. Produces quality plating.

No Immersion Tanks. Mobile Equipment.

Plating equipment can be moved to the job. Quick, easy to use with Dalic hand-stylus, power pack, and the Dalic plating solutions. Mechanized production can be devised.

Write for Descriptive Brochure.

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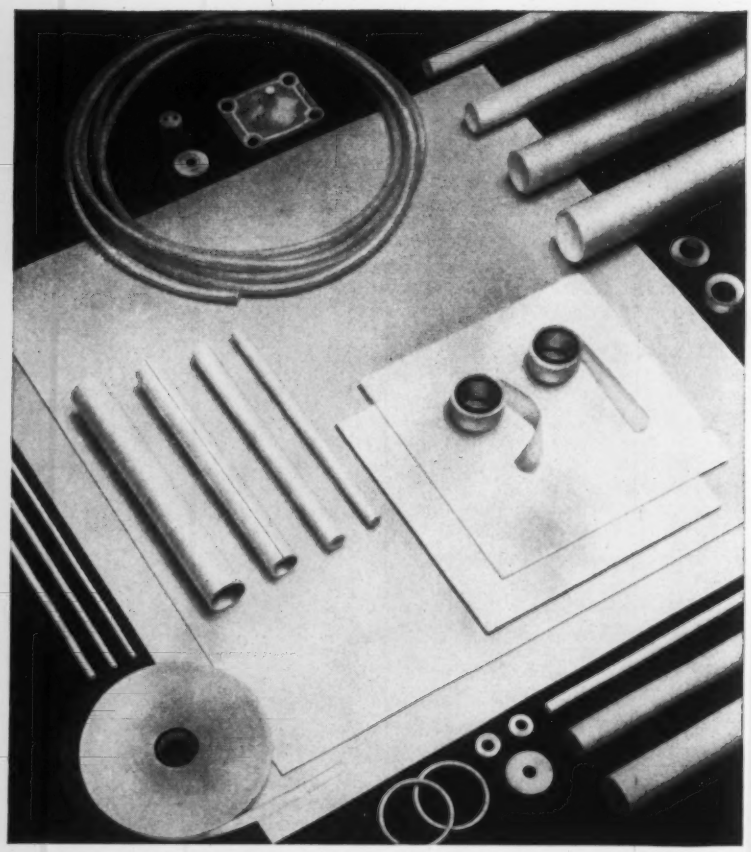

Now you can do even more with TEFLON – made bondable by R/M

Time was, you'd often rule out "Teflon"* where it was sorely needed, simply because you couldn't make anything adhere to it.

But not now. R/M has perfected a process that makes "Teflon" easily bondable to other materials and to itself with commercial adhesives. Now you don't have to design intricate "Teflon" parts in a single piece or devise elaborate and costly fastening methods.

R/M can supply "Teflon" sheets, rods, tubes, and tape with bondable surfaces where you specify them. Thus you can use the high dielectric strength and superior chemical resistance of "Teflon" without worrying about how to make it stay put. In fact, you can take advantage of bondability and nonbondability in the same R/M "Teflon" part.

A lot is happening in "Teflon" daily. To keep up with it, talk "Teflon" with R/M . . . and learn of R/M's *complete "Teflon" service* that can help you cut product costs without cutting corners. Call one of the offices listed below or write Plastic Products Division, Raybestos-Manhattan, Inc., Manheim, Pa.

*Du Pont trademark for its TFE-fluorocarbon resin

R/M

PLASTIC PRODUCTS DIVISION
RAYBESTOS-MANHATTAN, INC.
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For more information, turn to Reader Service card, circle No. 340

What's new IN MATERIALS

approximately 40,000 psi, compared to less than 1000 psi for tungsten.

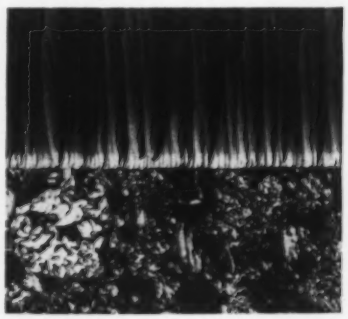
Its flexural strength is about 25,000 psi; that of ordinary graphite ranges from 1000 to 8000 psi. Because of its high density, sheets only 1 or 2 mils thick are impervious to liquids and gases. The material is also said to be many times more resistant to oxidation than conventional graphite because of its low chemical activity.

According to GE, the characteristics of pyrolitic graphite are dependably reproducible, whereas conventional graphite's characteristics vary from batch to batch.

Potential applications

Pyrolitic graphite is expected to

Pyrolitic graphite piece *is made in the shape of a nose cone heat shield. Model represents structure of the material.*



Structure *of pyrolitic graphite (top) is compared to structure of ordinary graphite (bottom). Pyrolitic graphite crystals are aligned in orderly stacks, whereas ordinary graphite crystals are arranged in a random manner.*

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For more information, turn to Reader Service card, circle No. 328

Roll Back The Thermal Barrier ....

with **CHROMALLIZING**

Oxidation and thermal shock resistance of metals used in jet engines and similar superheat applications are greatly improved with CHROMALLIZING. The patented and proven process of diffusing chromium with other elements into the surface provides an alloy case which is integral with the base metal. It can't peel or flake; the chromium and other elements diffuse uniformly into recesses, pores, cracks and even blind holes.

Alloy	Usual Operating Temperature	Operating Temperature of CHROMALLIZED Alloy
Iron Base (including stainless steels)	1500° F	SA CHROMALLIZED 310 and 321 stainless steels show no failure after 18 hours at 1950° F in an atmosphere containing lead bromide and lead sulfide.
Nickel Base	1800° F	U CHROMALLIZED nickel base alloys are unattacked after 200 hours at 2000° F.
Cobalt Base	1800° F	SAC CHROMALLIZED cobalt base alloys are unattacked after 150 hours at 2200° F.
Molybdenum	Over 2000° F	W-2 CHROMALLIZED molybdenum shows no failure after 400 hours at 2350° F, after 48 minutes at 2800° F, and after one minute at 3400° F.

Ordinary steel can also be chromallized to provide resistance to corrosion, oxidation and wear.

A recent Chromalloy development, IOCHROME (99.997% pure chromium), is a basis for chromium alloys for use at 2500°F.

Write for illustrated BULLETIN MH

Chromalloy corporation

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ELmwood 8-5900

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PROPELLEX CHEMICAL DIVISION, EDWARDSVILLE, ILLINOIS
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SINTERCAST DIVISION, YONKERS, N. Y. Machinable carbides & nuclear materials.

For more information, turn to Reader Service card, circle No. 392

What's new IN MATERIALS

find applications in missile nose cone heat shields, rocket engine nozzles, and the steering vanes of missiles. In addition, it may be used in industry as a strong, smooth-surfaced material for hot-pressing dies, and as a heat resistant material in melting crucibles for metals, ceramics and semiconductors. It may also prove useful in nuclear reactors where graphite is used to slow down neutrons.

(For information on another new type of graphite, see M/DE, Feb '60, p 16.) KEY NO. 616

New Process Cleans Copper for Plating

A new process for preparing copper for electroplating replaces the conventional acid pickle by a brief dip in a 25% solution of ammonium persulfate, followed by a warm water rinse.

The process is said to produce copper with an unusually clean surface that is free of oxides. It was developed by Becco Chemical Div., Food Machinery & Chemical Corp., Station B, Buffalo 7, N. Y.

In one typical case, a hard nickel electroplate (0.0003 in. thick) that had been deposited on persulfate-cleaned copper showed a 73% reduction in the number of pinholes compared to the same electroplate deposited from the same bath on an acid-pickled copper. KEY NO. 617

Bolt-Nut Combination Is Strong at 900 F

A new threaded bolt and nut combination for use in missiles and aircraft is said to be the first such combination capable of 200,000 psi tensile strength at 900 F. It has 260,000 psi tensile strength at room temperature.

The high temperature bolt, called EWB 926, is commercially available from Standard Pressed Steel Co., Jenkintown, Pa. It is supplied with a mating self-locking nut called FN 926.

Substantial aircraft and missile weight reductions can be effected with the bolt. For example, the de-

An assignment in migrating ions... for Lukens Application Research.

Corrosion. This is the metallurgical result of ion migration. It's a frequent opponent for the Lukens Application Engineer in his job of helping you determine the *best* steel for "problem" applications. In the case of miscellaneous-cargo tankers, for instance, corrosive hot caustics are often carried on one leg of a trip; on another... high purity glycerine that must not become contaminated. How, marine designers asked, can we get *economical* protection both for cargoes and hold tanks? Drawing on years of experience with process industries equipment, Lukens Application Research suggested the answer: nickel-clad steel—highly corrosion-resistant, comparatively inexpensive—with a special sodium hydride finish that is easy to clean, expedites conversion.

Experience and ingenuity are the stock-in-trade of Lukens Application Engineers. For personal assistance on problems of metals application—corrosion, cryogenics, metal expansivity, abrasion, structural stress—please contact us. Write Manager, Application Engineering, D80 Services Building, Lukens Steel Company, Coatesville, Pennsylvania. Also contact us for Clad Steel Equipment Bulletin No. D-80.

HELPING INDUSTRY CHOOSE STEELS THAT FIT THE JOB

For more information, turn to Reader Service card, circle No. 349

Use this **designers' check-list** for

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GRAPHITES

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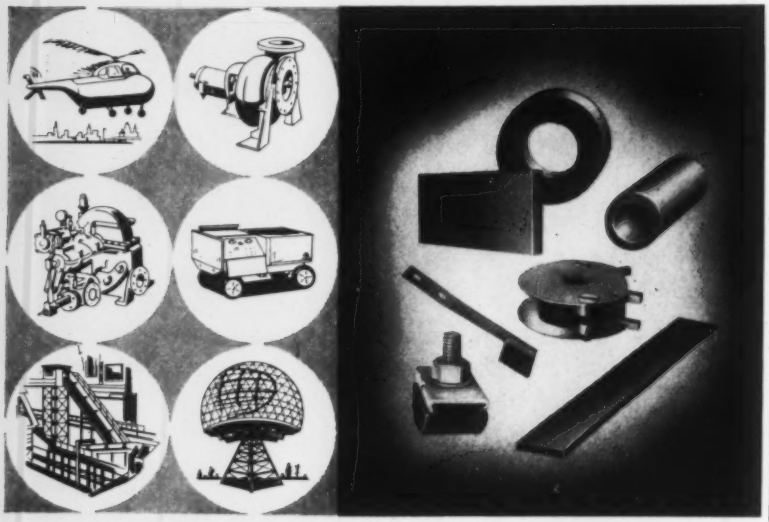
MY SERIES—Metallized carbon graphite. Provides extra-long life in difficult applications wherein operating conditions are severe.

PY SERIES—Non-metallized carbon graphite. Specially treated for use in high pressure seals.

EY SERIES—Provides exceptionally high-reliability in the presence of high temperatures (to 1000° F).



Self-lubricating Morganite possesses many different advantages capable of solving a wide range of operating problems. These dependable materials are specified for a broad list of components ranging from bearings in sealed mechanisms to electrical contacts operating in extremes of temperature.

Call or write for literature or recommendations on specific applications. Morganite sales engineers will be happy to explain the advantages of Morganite for use on original equipment or as replacement parts in your maintenance projects.

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For more information, turn to Reader Service card, circle No. 365

PROPERTIES OF EWB 926-FN 926 JOINTS

Temperature, F →	Room	900
Ult Ten Str, 1000 psi	260	200
Yld Str, 1000 psi	215	150
Shear Str, 1000 psi	156	120
Fatigue Str (65,000 cycles average), 1000 psi	135	115
Endur Limit (8 million cycles), 1000 psi	110	90
Stress Rupture Str (100 hr), 1000 psi	—	140

veloper says EWB 926 bolts two or three diameter sizes smaller than conventional high strength fasteners can be used without loss of holding power. Also, a ½-in. EWB 926 bolt can do the job of a ⅝-in. MS 20010 bolt and nut combination at a saving of 40% in fastener weight.

The bolt is made of a 5% chromium, high strength alloy steel. Nut material is aircraft quality alloy steel AMS 6304. The bolt and nut combination is finished with a diffused nickel-cadmium plate.

KEY NO. 618

Epoxy Adhesive Has High Strength

A high strength, one-part epoxy adhesive is being marketed by Minnesota Mining & Mfg. Co., Adhesives, Coatings and Sealers Div., 900 Bush Ave., St. Paul 6, Minn.

Properties

The adhesive, designated Scotch-Weld EC-1595, is said to provide metal-to-metal bonds with shear strengths of 2500 psi at 75 F. It is also said to maintain high strength over a temperature range of −67 to 300 F. The adhesive exceeds requirements of MIL-A-5090B (Class A) and MIL-A-8431 (Type 1) specifications.

The developer says the adhesive has high creep resistance under constant stress, good adhesion to metals and plastics, and excellent resistance to water, 20% salt spray, hydraulic oil and aromatic fuel.

Potential applications

The adhesive is self-filleting which makes it suitable for honeycomb sandwich constructions. The adhesive's paste-type consistency is said

with the fast service received from Curbell, Inc., Buffalo FIF fabricator. M-R-C needed 1500 Formica grade LN-42 ball bearing retainer ring blanks machined to precise length, ID and OD within 24 hours. Actually delivered in 14 hours!

FIF fabricator, Dutton Mfg. Co., El Cajon, California suggested a fabricated Formica part to replace an unsatisfactory molded part for this airframe fillet. Result: a better fillet delivered in time to avoid costly line stoppage.

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So, for *better* parts *faster,* be sure to contact your local FIF fabricator. Phone your Formica district office for his name and address, or write Formica Corporation, a subsidiary of American Cyanamid, 4550 Spring Grove Ave., Cincinnati 32, Ohio.

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For more information, turn to Reader Service card, circle No. 335

to provide excellent void-filling properties, permitting the structural joining of loosely fitting parts. Being 100% non-volatile, the adhesive is particularly useful for bonding impervious surfaces.

Curing

The optimum cure for the adhesive is 60 min at 300 F. However, cure time can be decreased by increasing cure temperatures; for example, it is cured in 2 min at 500 F. Only contact pressure is required during curing operations, and elaborate and expensive pressure fixtures are not needed, according to 3M.

The adhesive contains a latent hardener that is said to eliminate the need for accurately weighing and mixing a hardener with the base resin at time of use. In addition, 3M says the adhesive has an unlimited working life, and will not harden before curing operations are performed. KEY NO. 619

Other Adhesives Used from –67 to 160 F

Minnesota Mining & Mfg. Co., Adhesives, Coatings and Sealers Div., 900 Bush Ave., St. Paul 6, Minn. has also introduced three two-part epoxy adhesives that cure at room temperature under contact pressure.

According to 3M, all three adhesives maintain high strength properties over a service temperature range of –67 to 160 F. Designated as Scotch-Weld EC-1751, EC-1838 and EC-2054, they are used for high strength metal and plastics structural bonding applications where heat and/or pressure are not feasible in the bonding operation.

The adhesives are said to have high creep resistance under constant stress, good adhesion to metals and plastics, and good resistance to

PROPERTIES OF EPOXY ADHESIVES

Type →	EC-1751	EC-1838	EC-2054
Shear Str, psi			
–67 F	1400	1500	1400
75 F	2300	3200	3000
180 F	800	800	800

HARSHAW

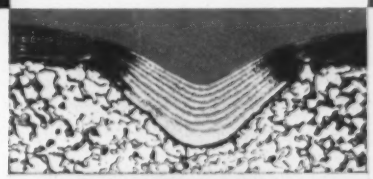
HARSHAW Airglow

AIR-AGITATED BRIGHT NICKEL PROCESS

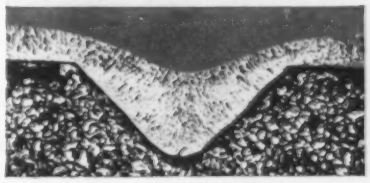
Gives you insurance against air supply failure because it operates efficiently with any agitation system.

Airglow allows the use of current densities much higher than attainable from mechanically agitated systems.

Levelling effects of Harshaw Airglow Bright Nickel deposit compared to that of Harshaw Perflow leveling semi-bright nickel.



TOP: Airglow Bright Nickel—1.5 mil deposit—depth of groove 3.1 mils.
BOTTOM: Perflow Semi-bright Nickel—1.5 mil deposit—depth of groove 3.2 mils.



- Airglow depth of color and brightness unequalled.
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water, hydraulic oil and aromatic fuels.

Potential applications

The good self-filleting properties of the adhesives is said to make them useful for honeycomb sandwich constructions. Their paste-type consistency provides excellent void filling properties, permitting structural bonding of loosely fitting parts.

Paste consistency is also said to make the adhesives useful as void fillers for repairing and filling holes, dents and cracks in metal parts, castings and sheet metal. The adhesives, being 100% nonvolatile, are particularly useful for bonding impervious surfaces.

Properties

The non-sag property of EC-1751 permits it to be applied in thick layers for contouring purposes. When cured, the adhesive can be sanded, machined and painted. Shear strengths of the adhesives at various temperatures are given in an accompanying table.

Curing

The developer says the adhesives will cure to maximum strength in approximately seven days. A more rapid cure can be obtained by heating an adhesive-bonded assembly in an oven under infrared lamps or by induction heating. **KEY NO. 620**

Expanded Metal Sold in Two New Patterns

Exmet Corp., 127 Marbledale Rd., Tuckahoe, N. Y. has added two new patterns to its line of decorative, expanded metal sheets. The patterns, called Dutch Hat and Wooden Shoe, are available in 0.050 and 0.100-in. thick aluminum sheets with pattern openings of approximately 1.25 by 0.40 in. Standard sheet sizes are 48 by 72 in. and 48 by 96 in.

The decorative sheets can be fin-

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Adaptaloy castings are easily cold formed and simplify assembly for the Sandfort Furniture Co., N. Y. Inset photo illustrates one of Sandfort's cast aluminum furniture settings—all are cast of Adaptaloy.

FEDERATED METALS DIVISION

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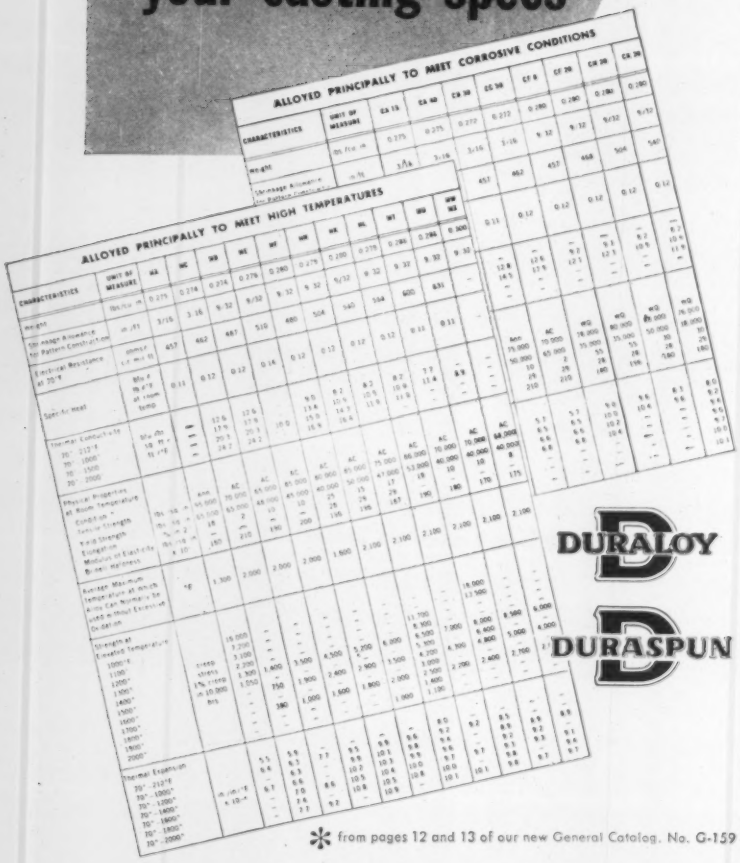
Chicago: Essex 5-5000

IN CANADA: Federated Metals Canada, Ltd.
Toronto, Ont., 1110 Birchmount Rd., Scarborough, Phone: Plymouth 73246

Montreal, P.Q., 1400 Norman St., Lachine, Phone: Melrose 7-3591

For more information, turn to Reader Service card, circle No. 391

* TABLES to help you select the proper alloy for your casting specs



* from pages 12 and 13 of our new General Catalog. No. G-159

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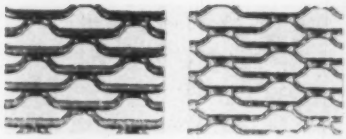
Whatsnew IN MATERIALS



***Decorative metal** is available in new Dutch Hat (left) and Wooden Shoe patterns (right).*

ished in a variety of colors by anodizing or by porcelain enameling.

The expanded metal is suitable for use as grills on air conditioners, radios, TV sets, heaters and other household items. The sheets are also suitable as grills and trim on automobiles. **KEY NO. 621**

Coating Absorbs Ultraviolet Rays

A new insulating and protective coating can be applied to fluorescent lights, windows and other ultraviolet ray sources in order to protect ultraviolet-sensitive objects such as semiconductor devices.

The coating, called HumiSeal X-242, was developed by Columbia Technical Corp., 61-02 31st Ave., Woodside 77, N. Y. It is said to have good weather resistance properties. Its dielectric strength is 1700 v per mil. Applied by brush, dip or spray, the coating dries and cures at room temperature. **KEY NO. 622**

Plastics Netting, Piping Are Strong, Versatile

Polyethylene netting and piping are being made by a new process in which polyethylene is extruded directly into tubular net form in one operation. By this technique, each strand intersection becomes an integral part of the material, even stronger than the individual strands, in contrast to die-cut, interwoven, or heat-sealed netting or tubing where the openwork pattern is made after the material is extruded.

The two polyethylene products, called Vexar, are now commercially available from the Film Dept. of E. I. du Pont de Nemours & Co., Wilmington 98, Del. They sell for

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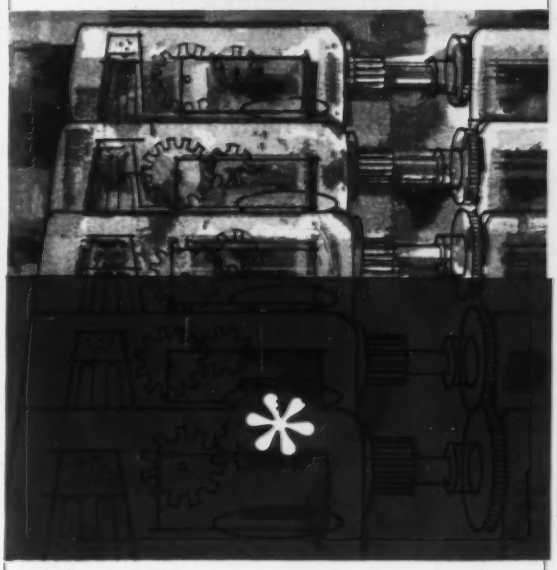

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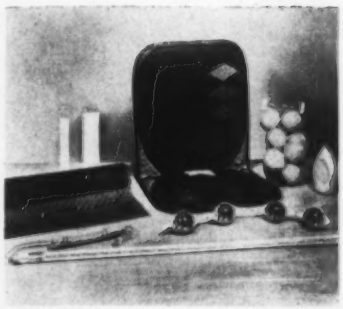

Typical applications *for Du Pont's new Vexar plastics netting and piping are shown above.*

$1.50 per lb. Netting and piping made of other thermoplastic materials are still under development.

Products retain properties of base material

Principal advantages of the new materials are their almost infinite variety of mesh size and pattern, filament diameter, strength, stiffness and color. In addition, the products are said to retain the chemical and physical characteristics of the basic resin. Thus, the initial polyethylene versions of Vexar netting and piping have the chemical inertness, flexibility and resistance to moisture, rot and mildew characteristic of polyethylene.

Three patterns available

Three basic patterns are available in most Vexar plastics netting and piping products. They are: 1) diamond, where intersecting strands are on the bias to the direction of extrusion; 2) twill, in which one strand parallels the extrusion direction and one is on the bias; and 3) plaid, a decorative version of the diamond pattern in which strands are grouped and spaced unevenly to provide a wide variety of effects.

Strand diameters can be made from 15 mils up, according to Du Pont. Mesh size can be varied from 16 counts to the inch, smaller than normal window screening, to more than an inch between strands, somewhat similar to the spacing in large fish nets or diamond-weave heavy wire fencing.

Applications

The plastics netting and piping are expected to be used in protective, decorative and packaging applica-

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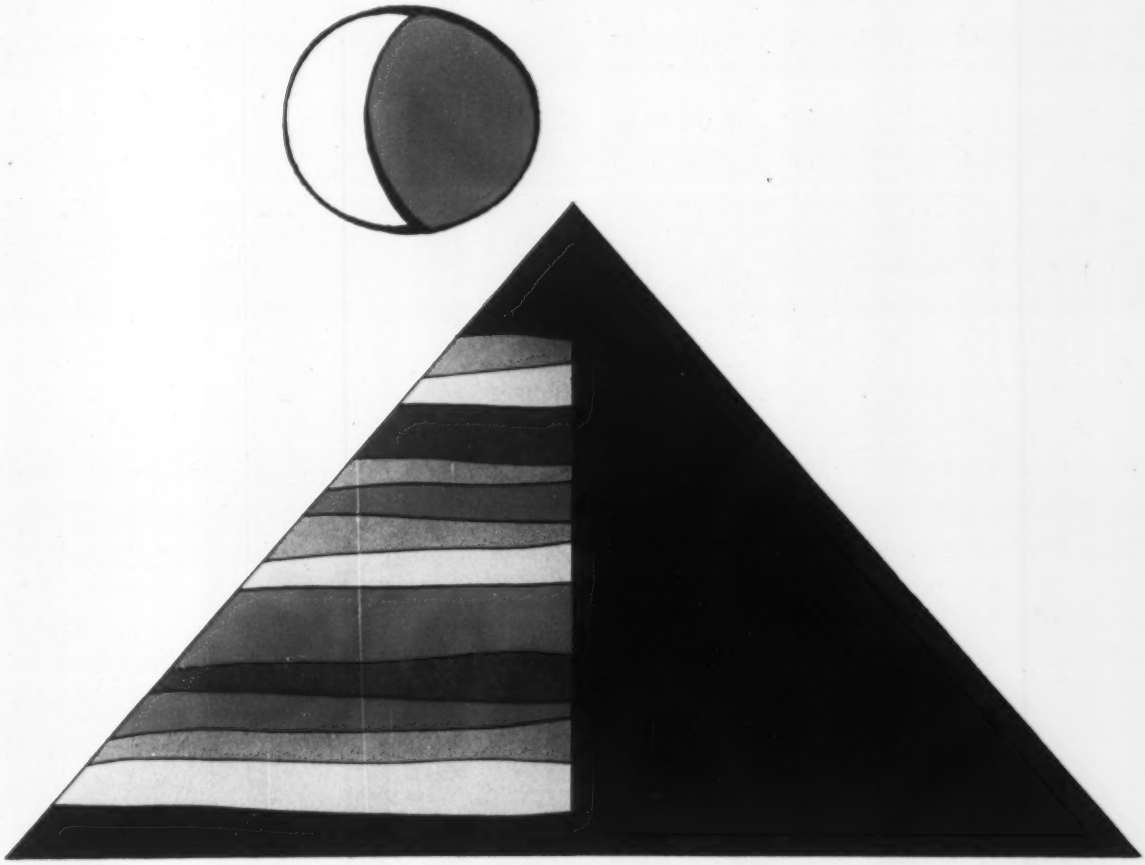

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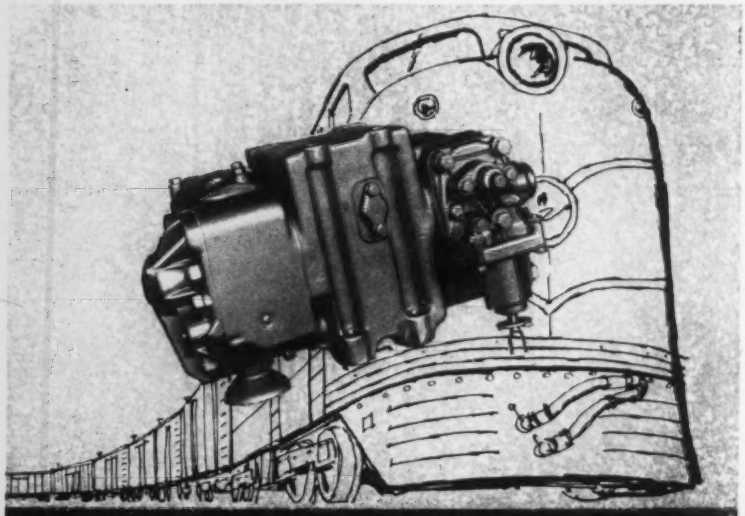
IF PHENOLICS CAN DO IT **PLENCO** CAN PROVIDE IT—AND DOES—FOR **WESTINGHOUSE AIR BRAKE**



WESTINGHOUSE AIR BRAKE PUTS A STOP TO IT
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When a freight car stops, many cargo-tons must be stopped with it . . . more today than ever before. Modern freight trains are longer, the engines more powerful; speeds are higher . . . *All this calls for more effective methods of retardation control—a better brake.*

"AB" freight car brake equipment developed by Air Brake Division, Westinghouse Air Brake Co., Wilmerding, Pa., has kept pace with such railroading progress through the years. Today's "AB" equipment provides for smoother train slack control. Damaging shocks are prevented with emergency transmission approximately *40% faster* than with former standard equipment.

At the heart of this modern brake-power is the "AB" Valve. And within the valve—the pistons. Because these pistons must work smoothly at all times, Air Brake Division engineers use piston bushings molded of Plenco phenolics. The Plenco phenolic molding compound specified by Air Brake Division possesses low and uniform anti-friction characteristics together with dimensional stability. It insures resistance to impact from piston "jogging" that would tend to cause bush grooving.

Piston bushings are, of course, a special kind of problem. *Your* problem or product surely has its own requirements. Special or not, if they call for understanding attention, broad experience with many industries, and ready availability of an extensive selection of *general* and *special-purpose* phenolic molding compounds—call on Plenco.

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tions, according to Du Pont.

For example, flat, flexible, black netting is used in portable auto seat pads to provide a nonclinging surface and to protect a decorative cloth underpanel. The same material is also used as display shelf lining and as a glassware drain cloth.

Semirigid Vexar piping is finding use as a protective sleeve over highly polished tubular machine parts, such as bearing shafts. The piping is also used as a protective and decorative sheath over a metallic heating element in a home closet dehumidifier rod. The plastics mesh prevents burning of hands on the metal tube.

In packaging applications, thin-gage, tubular Vexar netting can be used as inexpensive mesh bags for vegetables and fruit, and as decorative sleeves on pressure bottles and aerosol cans. A bag made of the netting can be slipped over the top of a pressure bottle or aerosol can and shrink-sealed by hot air. Not only does the jacket enhance the appearance of the container, but it also prevents shoppers from sampling the contents before purchase.

KEY NO. 623

Chopped Glass for Premix Compounds

A new fiberglass chopped strand with high strand integrity is said to make possible a more homogeneous premix molding material, resulting in greater uniformity in finished parts.

The chopped strand, called HSI, is available in ¼-in. lengths from Owens-Corning Fiberglas Corp., 717 5th Ave., New York 22. It sells for 44¢ per lb. The product is recommended for use in premix compounds that are to be compression molded.

The producer says the chopped strand has the following advantages:

1. Mixes in faster without clumping.
2. Improves compound flow.
3. Gives more uniform fiber distribution.
4. Improves strength uniformity by suppressing knit and flow lines.
5. Provides minimum surface dis-

For more information, circle No. 439 ➤

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FR-S 181—A light-colored, non-staining, non-discoloring lowest plasticity rubber, especially tailored to the processing of chemically blown sponge because mixing time is reduced and no peptizing agents are necessary.

FR-S 1000—An exceptionally versatile, general purpose rubber. Excellent results in most black or dark compounds. Easy processing characteristics; especially useful in making hard rubber products, such as molded and extruded goods, tire body stocks and treads.

FR-S 1001—Combines good aging properties with only slight stain and discoloration tendencies. Special end uses: light-colored shoe soles, heels, floor tiles, moldings and extrusions. Like all FR-S butadiene-styrene polymers, it is easily processed, highly uniform.

FR-S 1004—Low in water absorption and water-soluble impurities. Special uses: electric insulation and battery cases; can-sealing compounds and food jar gaskets. Good physical properties; ages well.

FR-S 1006—Ultra-light-colored, non-staining polymer; minimum of costly white pigment required; adds impact strength to light-colored plastics. Special uses: white sidewall tires, floor tiles, coated fabrics, shoe soles, household goods.

FR-S 1007—Low voltage electric grade rubber with low water-absorption properties. Special uses: electrical applications as in wire and cable insulation; excellent for a variety of hard rubber articles and gaskets.

COLD RUBBER TYPES

FR-S 1500—High tensile; easy to

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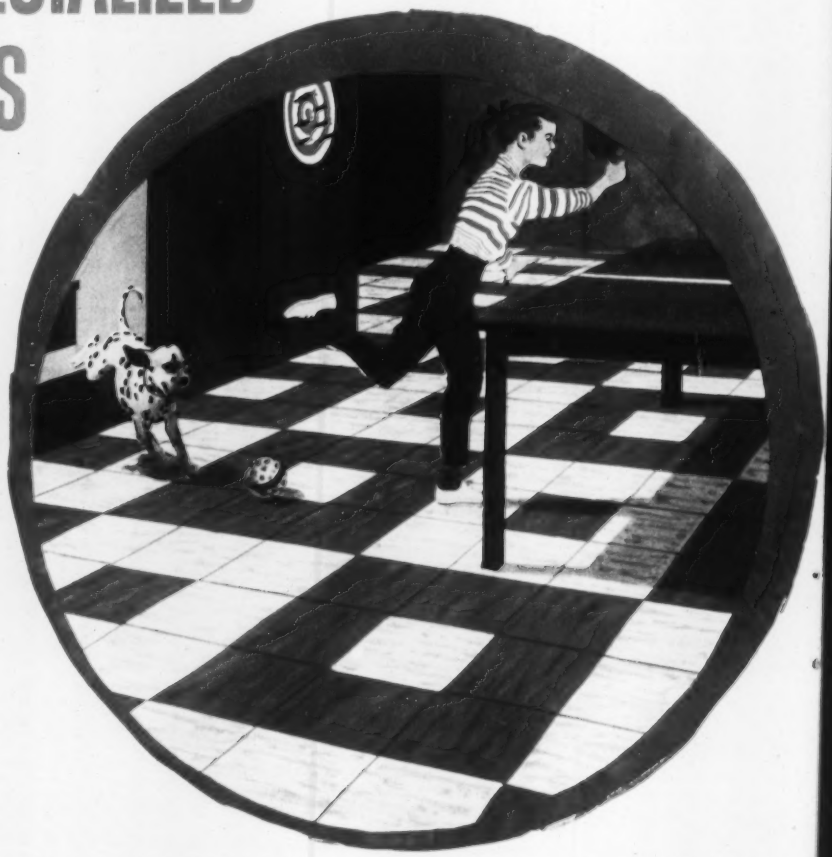
FR-S 195, SOLUBLE IN STYRENE, SHATTERPROOFS PLASTIC "PILL BOXES." Exceptionally light colored and non-staining, FR-S 195 is "*the* finest polymer" for products of high-impact polystyrene: plastic cases for radios, razors, cosmetics, etc. Breakage is minimal. Rigorously inspected to polystyrene standards for cleanliness, viscosity, dissolving time, FR-S 195 with styrene shows no yellow, gels or cloudiness, nor imperfections from faulty mixing such as fisheyes and orange peel.



RUBBER TILE BREAKTHROUGH! **FR-S 147** NOW OFFERS ALL THE PROPERTIES REQUIRED FOR TOP TILE SERVICE. FR-S 147—a super-refined rubber with a better-than-ever finish—now brings faster processing and low, low costs to rubber tile. One plant reports almost doubling its processing of rubber flooring mix with FR-S 147. Now rubber can prove and *sell* its competitive advantages over other tiles—by profitably matching their price appeal.

process; good building tack. Special uses: camelback, all tire stocks, hard rubber and mechanical goods and any products requiring premium physical properties.

FR-S 1502—Light color; non-staining; high loading capacity; flex-resistant. Special uses: white sidewall tires, kitchenware, hospital goods, sporting goods, coated fabrics, shoe soles and heels.

FR-S 146—Light color; non-staining; low plasticity; easy processing. Excellent for chemically blown sponge products, shoe soles, sporting goods, extruded items and a variety of mechanical goods.

FR-S 179—A base polymer for oil-extending rubber; extremely high viscosity. Economical, it allows compounder to add amount and type of plasticizer as desired. Good physical characteristics; excellent for mechanical goods.

OIL-MODIFIED TYPES

FR-S 184—New, improved, stabilized for tread rubber use oil masterbatch; 37.5 parts aromatic oil. Special uses: quieter riding, squeal-resisting tire treads that deliver extra mileage, camelback, mechanical goods and extruded parts. Distinctive for stability in storage, mixing and extruding.

FR-S 1710—This outstanding rubber combines 37.5 parts of non-volatile aromatic oil with a specially prepared polymer. Easily processed; more economical compounding of tire treads, mechanical goods, molded parts.

FR-S 1712—Combines a highly aromatic non-volatile oil with a specially prepared polymer. Great savings in manufacturing tire treads, camelback, motor supports, auto insulators. Its physical properties permit use of additional oil when added economy is desired.

FR-S 173—A greatly improved polymer in color, cured hardness and processibility. Used in mats, shoe soles and extruded and mechanical goods. Contains a non-staining antioxidant and 25 parts of a light-colored naphthenic oil.

FR-S 178—An economical, light-colored, non-staining rubber, extended with 37.5 parts of naphthenic oil. Offers improved color, cured hardness and processing properties particularly desirable in mats, shoe soles and extruded and mechanical goods.

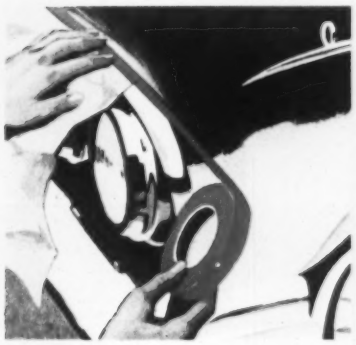
SPECIALTY TYPES

FR-S 1009—A non-staining polymer used with other rubbers to smooth out and speed up calendering and tubing and to avoid distortion of uncured products. Increases dimensional control in manufacturing insulated wire, hose, calendered sheet goods, coated fabrics.

FR-S 1012—High polymer viscosity, combined with solubility in solvents. Widely used for asbestos sheet, packing, gaskets, brake lining and high viscosity cement; non-staining; high tensile strength and high modulus when cured.

FR-S 1013—A special-purpose, high-styrene rubber used in closure and can-sealing compounds. Low content of water-soluble properties, low water-absorption properties and relatively high uncured strength. Produces strong adhesives, may be used in contact with light finishes.

FR-S 1014—Made with a rosin soap emulsifier; offers exceptionally good tack and green tensile properties. Widely used in adhesives, can-sealing compounds, industrial tapes.



MASKING TAPE WITH **FR-S 182:** A COST-CUTTING PRODUCT IN ADHESIVES AND OTHER APPLICATIONS. A non-staining, non-discoloring styrene butadiene copolymer, FR-S 182's light color and high uncured strength make it particularly suitable to developing exceptionally strong adhesives. Other applications: can-sealing compounds, coated fabrics, molded and extruded products. Low in water-soluble impurities, FR-S 182 also has low water absorption characteristics; has a bound styrene content of 43 per cent.

NEW **FR-S 201:** A LOW-PRICE, NON-STAINING POLYMER THAT REDUCES COMPOUNDING COSTS. *The* most economical rubber, new, further-improved FR-S 201 is a perfected 50-part oil-extended polymer that reduces compounding costs to a new low. Its non-staining and light color characteristics—and its low cost—tailor it to volume use in such products as refrigerator door gaskets, rubber matting, housewares, appliance parts.

HIGH-STYRENE MASTERBATCH **FR-S 158** ELIMINATES DIFFICULT AND COSTLY MIXING OPERATIONS. A 50-50 masterbatch of 1502 and a reinforcing high-styrene resin, FR-S 158 is compounded in the latex state for perfect dispersion and fast, efficient mixing operations. Shipped in easily compounded pellets, FR-S 158 imparts special stiffness or hardness, good physical characteristics, abrasion resistance, moderate flex resistance to light-colored rubber products, such as shoe soles, flooring, high-pressure tubing.

FR-S LATICES

with the precise characteristics and production economies you are looking for

FR-S 200—THE NEWEST AND MOST OUTSTANDING SYNTHETIC LATEX DEVELOPED FOR THE FOAM RUBBER INDUSTRY. Designed for use in all foam applications, either 100% or in combination with some low-ammonia natural latex. Properties: superior processing characteristics, very high solids content provides excellent gel sensitivity, good structure, accepts higher pigment loading.

LOW-COST FR-S 176 FOR TEXTILE-COATING COMPOUNDS. For carpet and upholstery backing that upgrades feel and appearance in any fabric—for better adhesives, for saturated papers—FR-S 176 is, *penny for penny*, the highest solids latex available (49% solids). Highly resistant to ultra-violet light, heat aging, gas fading. Stable to mechanical action and to compounding ingredients. Another economy plus: its reduced water content means less drying time. Whatever your problems, your compounder can use this cost-shaving latex to your distinct advantage.

FR-S 174 PROVIDES INCREASED "HAND," MORE STIFFNESS AND STRENGTH IN CARPET-BACKING COMPOUNDS. Tufts locked in, problems locked out—that's the sales-stimulating story of FR-S 174 when used in carpet-backing compounds! A styrene-butadiene resin latex, FR-S 174 is an ideal stiffening agent for both natural and synthetic latices. It provides increased "hand," rigidity and rip strength for carpet-backing and foam. 50% solids.

FR-S 2000—The most widely used latex for its economy, stability and high tensile strength. Used for flexible, durable upholstery, textile and carpet backing; or with resins to saturate tire cords for greater adhesion. Good for pigment and fiber binding. 42% solids.

FR-S 2001—Outstanding for paper saturation in both beater and web processes. Used to increase flexibility and tear strength. Highly stable, and offers lower molecular weight for better adhesion, still retaining good tensile strength. 42% solids.

FR-S 2002—For premium back-sizing applications requiring extra light color. Excellent for upholstery and pile carpet; will not discolor conventional dyes. Can be sulphur-vulcanized; provides flexible coatings and films with very good strength. 50% solids.

FR-S 2003—A high-solids latex specially desirable where light color and low cost are important. Cuts costs by improving foam compound stability. Also used as a resin and plastics additive for better strength and flexibility. 60% solids.

FR-S 2004—A polybutadiene polymer latex which has a particular application in the manufacturing of high-impact plastics. It also is excellent for specialized latex foam uses, where light color and freedom from odor are important. 59% solids.

FR-S 2006—A superior chewing gum base, this latex may also be co-coagulated with rubber pigments for dry masterbatches with excellent dispersion and good processibility. Increasingly popular for asphalt paving and roofing. 28% solids.

FR-S 2105—A general purpose high-solids latex combining high tensile strength with low-temperature flexibility. Cuts manufacturing costs of foam products and offers excellent strength, flexibility and pigment loading capacity for backing and sizing of carpets and textiles. 62% solids.

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tortion and rippling.

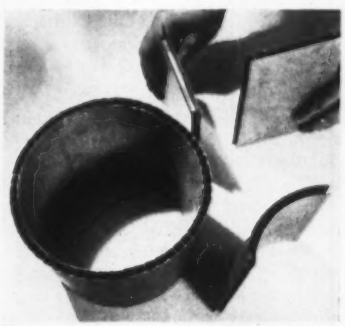
6. Permits greater freedom in formulation at high glass levels.

Premix compounds reinforced with the new chopped strand are expected to find major use in large-area, thin-walled parts.

(For an up-to-date report on premix molding, see M/DE, May '60, p 12.) KEY NO. 624

Asbestos-Rubber Sheet Resists Acids, Solvents

Hypalon rubber (Du Pont's chlorosulfonated polyethylene) is used as the base in a new compressed asbestos-rubber sheet packing developed by Keasbey and Mattison Co., Butler Ave., Ambler, Pa. In laboratory and field tests, the new material has shown good resistance to inorganic acids, such as sulfuric, hydrochloric, and pickling solutions,



Brazed honeycomb structures—The parts shown here were produced by a new "cold wall" brazing technique developed by Boeing Airplane Co., Wichita, Kan. Main features of the new technique include placing the heating elements next to the structure being brazed, adding a cooling system and eliminating costly metal envelopes for each part.

Because heat is concentrated where needed, some test panels have required only 21,000 Btu, compared to 1,500,000 Btu needed for similar panels in conventional brazing.

According to Boeing, the complete cycle time for purging, brazing, cooling and unloading is one-tenth or less of the time previously required. KEY NO. 625

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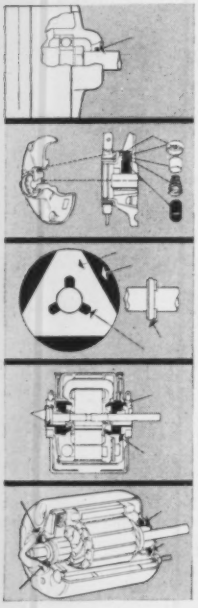
Seals . . . wicks . . . lubricators . . . washers . . . gaskets — are all vital electric motor parts that benefit from Felt by Felters.

A special Felters' "Engineered Fabrication" processes felt to specific thickness, density, hardness, and resiliency; and provides special characteristics such as absorption, stiffness, water repellency and flameproofing.

And, new felt and plastic laminates, called PlastiFelts, use synthetics such as Nylon, Teflon, Hycar and rubber to provide an even wider range of application, plus greatly improved performance.

These are some of the many electric motor applications where Felt by Felters offers both a low-cost and high performance material for non-metallic parts.



Felt seal inserted around shaft opening retains grease and keeps out foreign matter.

This self-oiler uses a felt wick, bearing against the shaft under spring pressure, for constant lubrication.

This is a thrust washer designed for double duty as a lubricator by the use of a felt ring and lubricating notches.

Lifetime bearing lubrication is possible by selection of correct SAE grade, and designing into sealed bearing.

Felters' "Engineered Fabrication" makes it possible to specify felt shapes for a complete motor and shaft lubricating system, combining reservoirs, and wicking, and directing oil flow to all required areas.

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as well as organic acids, aromatic hydrocarbons, and alkalis such as caustics.

The developer says the packing, called No. 903, is not subjected to cold flow under compression. Compressibility is approximately 20% and recovery a minimum of 40%.

The material is designed for such uses as gasketing on flanges, condenser heads and pump casings. It is available in five thicknesses, from 1/64 to ⅛ in., in sheets 50 by 50, 50 by 150, and 150 by 150 in.

KEY NO. 626

Epoxy Resins Used for Casting, Coating

Two new epoxies—a two-part casting compound and a one-part coating powder—are now on the market.

1. Casting compound

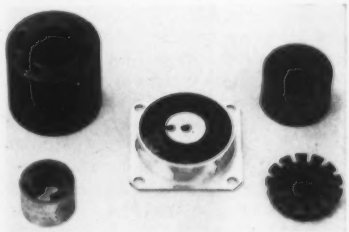
Hysol 15-032 is the name of the new, non-burning, self-extinguishing, flexible epoxy casting compound introduced by Hysol Corp., Olean, N. Y. The two-part, filled compound is recommended for use on transformers and other electrical and electronic parts. The compound is supplied white and colored.

KEY NO. 627

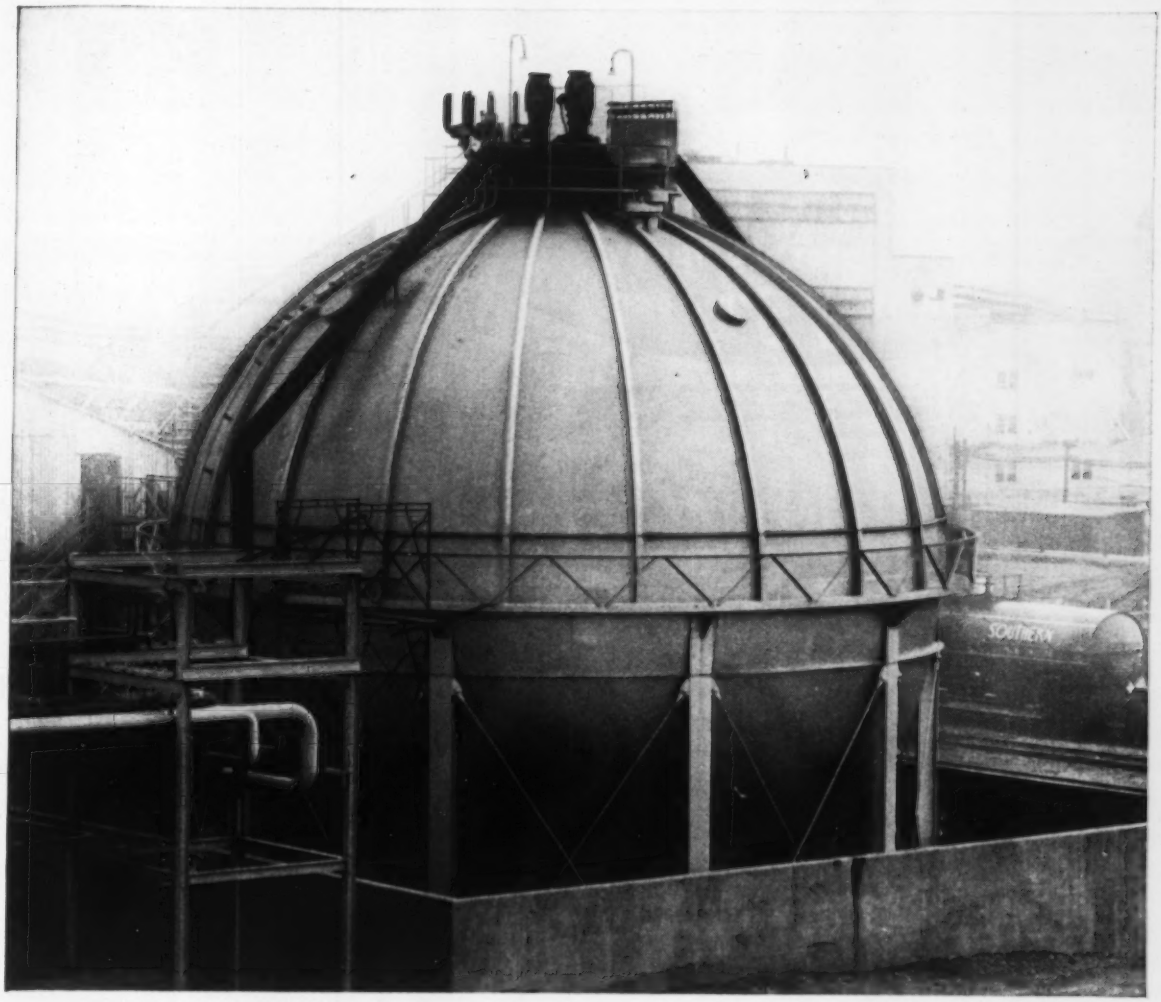
2. Coating compound

The one-part coating compound was introduced by Minnesota Mining & Mfg. Co., 900 Bush Ave., St. Paul 6, Minn. Called Scotchcast XR-5026, the product is available in a test kit which serves also as a powder aerator for experimental applications of the resin. The kit sells for $25.

Principal use of the resin is in coating and moisture proofing stators and rotors, resistors, capacitors, printed circuits and other intricately



***Typical parts** that can be coated with 3M's new, one-part epoxy resin powder.*



2¼% nickel steel tank stores 2000 tons of liquefied chlorine at −30°F... safely

20-year service record in many installations proves this nickel steel dependable for storage of liquefied gases down to −75°F.

In two decades of service in the recommended temperature range, there has never been a single incident of field failure of any 2¼% nickel steel vessel.

This record alone would be proof enough. But here's more:

- The *only* material approved for ocean shipment of liquefied propane is 2¼% nickel steel. Temperature: −44°F.
- This steel conforms to ASTM Specifications A203 (Grade B) and A300. It readily exceeds the minimum specified impact requirement of 15 ft-lb. keyhole Charpy at −75°F.
- The standard welding and forming operations are performed on 2¼% nickel steel without difficulty.
- The ASME Boiler and Pressure Vessel Code allows design stresses to 17,000 psi using 2¼% nickel steel.

Knowing these facts, it's easy to see why Columbia-Southern approved this material for this 2000-ton-capacity sphere. It bulk-stores chlorine at −30°F and at atmospheric pressure. Now in service 4 years, the tank fulfills every expectation of the fabricator, and of Columbia-Southern Chemical as well.

If you'd like complete data on 2¼% nickel steel, and other nickel alloy steels for service at temperatures as low as −320°F, write for your copy of "Properties of Nickel Steel Plates at Low Temperatures." Just drop a postcard to:

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67 Wall Street INCO New York 5, N. Y.

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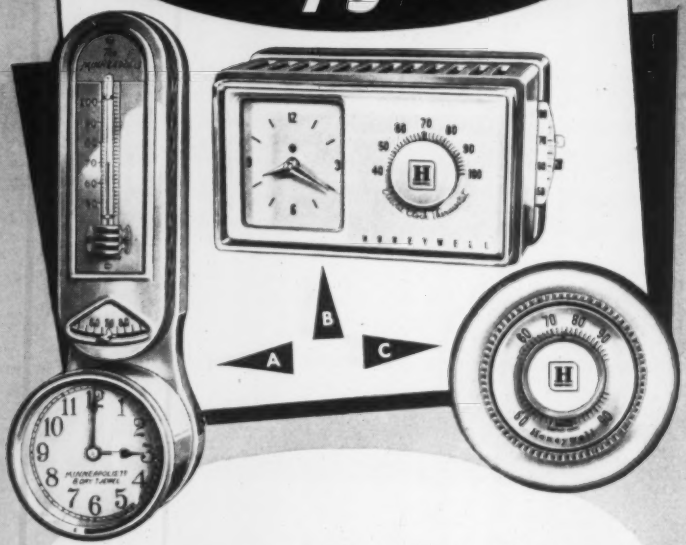
Congratulations

Minneapolis—Honeywell Regulator Company in its 75th year



A small company used its first thermostat as a part of the "damper flapper"—a control unit which operated the damper on a coal fired furnace. Thus, automatic heating was born in 1885.

The company became known as Minneapolis-Honeywell and for 75 years has been recognized as a leader in the development of thermostats and heating controls. The famous clock thermostat ("A" above) appeared in 1906. It featured a big, brassy, eight-day clock. A far cry from this original masterpiece is Minneapolis-Honeywell's modern, precision built and attractive electric clock thermostat ("B" above). This newest clock thermostat automatically adjusts room temperature to the living schedule—constant warm temperature by day, cooler room temperature by night.

The actuating elements in Minneapolis-Honeywell's new thermostats—both the electric clock model and the revolutionary round thermostat ("C" above)—are made of Chace Thermostatic Bimetal. Chace has been supplying Minneapolis-Honeywell with precision thermostatic bimetal since 1925 . . . a long and productive relationship, indeed.

We, at Chace, are proud that we have been contributors over the years to the success of such a great company.

Happy 75th anniversary, Minneapolis-Honeywell!

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1615 BEARD AVE., DETROIT 9, MICH.

For more information, turn to Reader Service card, circle No. 417

ELECTRICAL PROPERTIES OF XR-5026

Dielectric Strength, v/mil	500-800
Dielectric Constant (74 F, 60 cps)	3.61
Dissipation Factor (74 F, 60 cps)	0.0053

shaped objects. The powdered resin can be applied by fluidized bed coating or by spraying.

The resin is said to have good cut-through resistance in stator applications, and a high impact strength. In tests, an 8 lb ball dropped from 6 ft on a 0.015-in. thick coating applied to ⅛-in. thick steel plate resulted in no cracks in the coating.

KEY NO. 628

High Strength Steel Sold by Five Firms

A previously announced low alloy constructional steel (see M/DE, Apr '60, p 214) is now available from five companies. They are U. S. Steel Corp., Latrobe Steel Co., Allegheny Ludlum Steel Corp., Universal-Cyclops Steel Corp. and Scaife Co.

The steel described in the April issue of this magazine was Universal-Cyclop's version, called Unimach UCX2. Properties, composition, heat treatment, machinabilty and fabrication of the steel were discussed.

The steel, which has a 275,000 to 290,000-psi tensile strength, was developed at Mellon Institute in cooperation with Scaife Co., Anne St., Oakmont, Pa. Scaife's version is called MX-2 and is available in all standard mill forms.

The new steel is a cobalt modification of the AISI 4100 series type of steel. Compared to other high strength steels, it appears to have the least sensitivity to weaknesses created by notches, cracks and heat treatment.

KEY NO. 629

Tooling Compound Useful up to 3000 F

A ceramic tooling compound can be readily molded by pouring a mixture of the material and water into

General Electric RTV* liquid silicone rubber

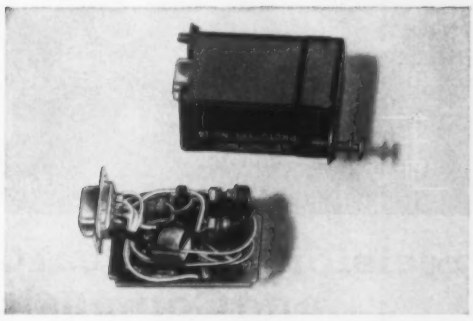
*Room Temperature Vulcanizing

New low viscosity for easier encapsulation and impregnation

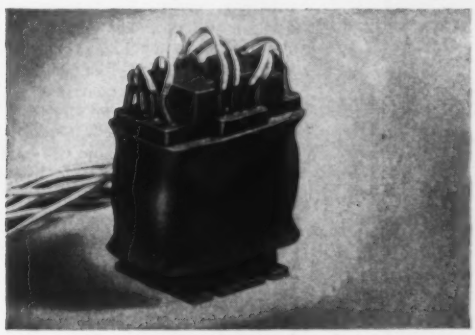
The latest addition to General Electric's RTV family offers lower viscosity than any other available silicone rubber compound — a typical viscosity of 120 poises. Easily pourable, it flows freely in and around intricate contours, making it ideal for protecting electrical and electronic components.

With RTV's new low viscosity, the range of G-E RTV compounds now extends from 120 to 12,000 poises. You can now meet your specific requirements by selecting from several G-E RTV compounds, all of which offer room temperature cure, heat and ozone resistance, and good electrical properties. Write for a free test sample, briefly describing your application.

General Electric silicone rubber used extensively by Aerojet-General Corp. for the Titan ICBM's propulsion-system wiring harness. Tubing is heat-cured silicone rubber, molding G-E RTV and wiring insulated with silicone rubber — all chosen for their stable insulating properties, resistance to temperature extremes and weathering, and stability in storage for many years.



Sight amplifier module potted with RTV by the Armament and Control Section of G.E.'s Light Military Electronics Department. Used on the Lockheed CF-104 and F-104G jet aircraft, RTV provides mechanical support and vibration damping, protects unit against moisture and ozone. (Bottom photo shows module before potting.)

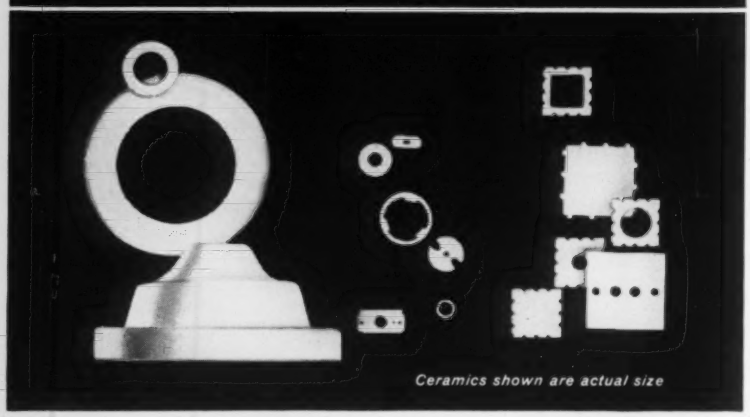


High-voltage, high-altitude transformers from Laboratory For Electronics, Inc. are encapsulated with General Electric RTV to meet MIL-T-27A specs. This prevents flashover at maximum ratings of 2200 volts rms and 80,000 feet. General Electric RTV was selected for its good heat transfer, low viscosity and mechanical strength.

GENERAL ELECTRIC

Silicone Products Department, Waterford, New York

For more information, turn to Reader Service card, circle No. 359



Precision Technical Ceramics and Composites

CFI Corporation provides integrated skills and facilities specifically adapted to the design, prototype development and production of high-temperature ceramics, components, ceramic-metal vacuum composites, glass-metal seals and specialized body compositions.

Typical ceramic products include modular forms, spacer and abrasion-resistant elements, metallized parts, multi-terminal composites, compact high-temperature power lead through elements and envelope assemblies.

Body compositions comprise high Alumina, Steatite, Forsterite, and customized materials, such as Series 1000 LOSSY ceramic for microwave attenuation.

For complete details on CFI custom-designed ceramics and ceramic-metal composites to fit your specifications, call CFI today. We're ready to work with you right now!

CFI *An Integrated Ceramics Service*

CFI Corporation
Department MD, Cottage Place
Mineola, New York—Pioneer 6-0571

Gentlemen: Please send me, without obligation, the following literature on CFI ceramics:

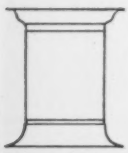
☐ "Custom Ceramic Parts for Industry" Brochure
☐ Microwave Ceramics Spec Sheet
☐ Have technical representative contact me.

Name_____

Title_____

Company_____

City_____ Zone_____ State_____



Send for free CFI ceramics data

For more information, turn to Reader Service card, circle No. 454

What's new IN MATERIALS

Brazing fixture *molded of new ceramic compound cost $45 and replaced a similar fixture made of Inconel that cost $425.*

a plastics mold and then allowing it to set up in air. After a low temperature bake to remove moisture, the material is ready for use at temperatures up to 3000 F.

The new material is called Duramic S-2 and is available from Duramic Products, Inc., 426 Commercial Ave., Palisades Park, N. J.

It is recommended for brazing and welding fixtures, hot forming dies, and sintering and diffusion boats. It can also be used as a high temperature encapsulant for heating coils and resistance heating elements.

The new product is supplied in a sample kit costing $27.50. The kit contains the ceramic tooling material and a plastics molding compound. KEY NO. 630

Wear Resistant Steel Is Easy to Machine

A new oil-hardening tool steel is now available in the form of billets and bars from Darwin & Milner, Inc., 2222 Lakeside Ave., Cleveland 14. The graphitic steel is said to have excellent resistance to abrasive wear, galling, scuffing and scoring.

The developer says the tool steel is easy to machine because its carbon content is uniformly distributed as free graphite. The material, called Dargraph, is an AISI-SAE type 06 steel.

According to the developer, wear plates made of Dargraph last longer

HERE ARE COMPANION PRODUCTS TO MAKE YOUR FIGHT AGAINST CORROSION...

less costly— more effective

They are: Tygorust — a primer that locks protective coatings to damp or dry rusted steel; and Tygon "ATD"* Hot Spray vinyl which builds up a film thickness of 5 mils or better in just two passes of a spray gun.

Cost savings are big. First of all, surface preparation costs are reduced materially. Second, material costs are lessened because Tygon Hot Spray requires no thinners. Third, application costs are lowered because two spray passes give a film thickness equal to five coats of conventionally applied paints. Fourth, longer life means lower maintenance costs, less frequent recoating.

But cost savings are, in a sense, the least important part of the story. You get better protection, more complete protection, longer lasting protection from corrosive attack.

*ADHESION
THICKNESS
DENSITY

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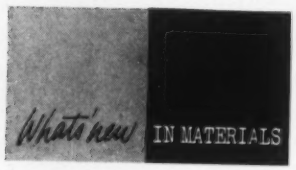


than conventional wear plates because of the steel's anti-friction characteristics and high impact resistance.

The material can be heat treated over the temperature range 1475 to 1550 F. Oil quenching produces a Rockwell hardness of C63-66.

KEY NO. 631

Treated TFE Tape Can Be Encapsulated

A new pressure sensitive TFE tape is made of a silicone rubber adhesive and a skived TFE backing to which a special primed surface is applied. Big advantage of the tape is that it accepts encapsulating resins and electrical varnishes, permitting manufacturers of small electronic parts to varnish dip or encapsulate over the insulating TFE surface.

Another advantage: the tape can be marked with almost any commercially available ink.

The tape, designated Temp-R-Tape TSP, meets Class H (360 F) insulation requirements. It is available from Connecticut Hard Rubber Co., 407 East St., New Haven 9, Conn. in 18-yd rolls, $\frac{1}{2}$ to 1 in. wide. Total thickness of the tape is 0.006 in. A $\frac{1}{2}$-in. wide by 18-yd long tape sells for $8.

KEY NO. 632

Fire Retardant Enamel Used on Wood, Metal

A fire retardant enamel based on a nonvolatile, chlorinated alkyd resin solution has been developed by scientists at the Industrial Test Laboratory of the Philadelphia Naval Shipyard.

Key ingredient of the enamel is chlorendic acid, a dibasic acid incorporating more than 50% by weight of stable chlorine. Marketed commercially as HET (R) acid and produced by the Eastern Chemical Div. of Hooker Chemical Corp., Niagara Falls, N. Y., the acid becomes a permanent part of the chemical structure of the new enamel and does not adversely affect other properties of the coating.

The enamel has passed a Navy

R B & W FASTENER BRIEFS

MAKING THE MOST OF MODERN MECHANICAL FASTENING

Technical-ities

By Fred E. Graves

Fastening of gasketed joints

The right fastener for a "flexible" joint rests on type of gasket material and its compressibility. Total preload on all the fasteners in the connection must be enough only to compress the gasket and provide sufficient additional clamping force to withstand the hydrostatic test pressure. More than this brings on a good chance of leakage, through "bowing" of the clamping plate.

Exaggerated sketch showing how too much torque tends to distort clamping plate and leads to leakage.

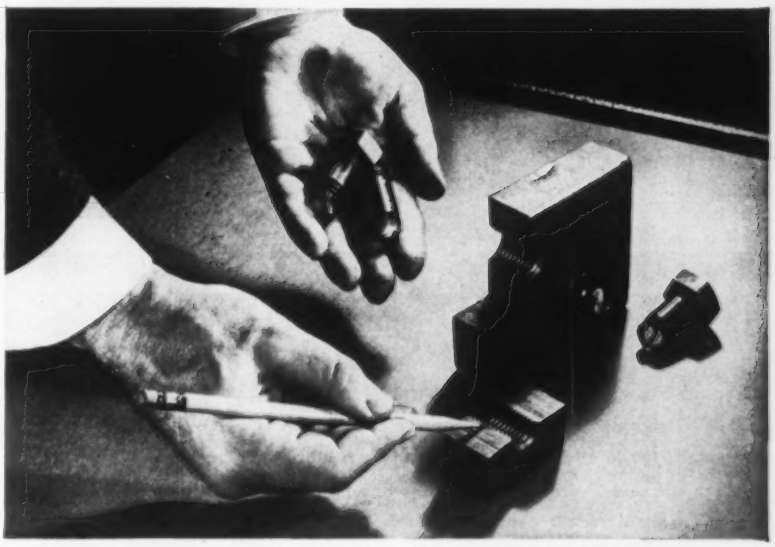
HYPOTHETICAL CASE

Suppose a joint is tightened with Grade 5 Hex Screws to their yield strength, and leakage develops. By going to alloy screws and tightening still further you would still get leakage. But Grade 2 Hex Screws, all torqued evenly, would no doubt solve it.

ACTUAL CASE

The fasteners on one product's flange had to withstand a 4000 pound hydrostatic pressure. But the hard asbestos gasket used took a bolt load of 28,000 pounds for sufficient compression to seal. By substituting a rubber and fibre gasket in this case, bolt load could be reduced. So could bolt size, thereby saving 73% on fasteners.

Using Hex Screws in tapped holes saves money



In the cast "coupon" shown above, the hex screws were torqued tight and removed 50 times—then torqued to failure. Note in the cutaway that the casting's threads are still perfect with no sign of stripping. It was the screws which broke—a clear demonstration that castings fastened with hex screws will suffer no thread damage during repeated disassemblies.

TWOFOLD BENEFIT

When there are no space clearance problems or other special requirements, using studs of 1-inch diameter or smaller often penalizes the user. First, in direct costs, since the more economical hex head screws will do the job to specification. And second, in production costs, since studs require that tapped holes have an *interference* thread fit, which in turn results in slow, "selective" assembly to determine properly mated threads. Hex screws need only a *clearance* fit, assemble faster.

ACTUAL EXAMPLE

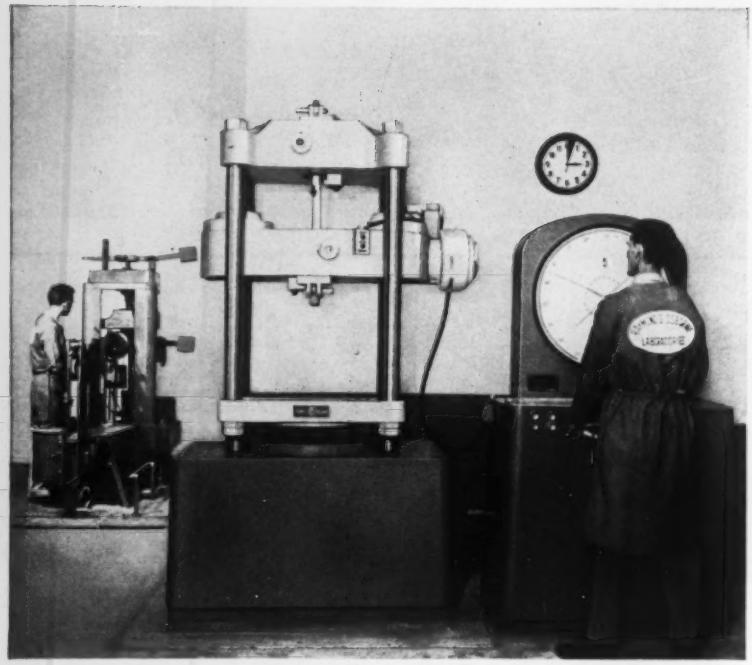
In one of his surveys of fastenings used by one company, the RB&W engineer pointed out that over 250 stud fastenings were being used in a large refrigeration unit. The same number of hex screws, costing $8.45, saved $22 over the studs and nuts. Annually, the total would be $7,800 on the production run of this unit.

Not to be overlooked either was the tangible saving on the less critical tapping job required.

RB&W offers its help on your specific fastener problems, or an overall survey of your fastener usage. Contact Russell, Burdsall & Ward Bolt and Nut Company, Port Chester, N. Y.

Plants at: Port Chester, N. Y.; Coraopolis, Pa.; Rock Falls, Ill.; Los Angeles, Calif. Additional sales offices at: Ardmore (Phila.), Pa.; Pittsburgh; Detroit; Chicago; Dallas; San Francisco.

For more information, turn to Reader Service card, circle No. 372



OSBORNE LABS KEYNOTE OLSEN'S 80 YEARS OF TESTING PROGRESS

Although the mechanical beam balance testing machine on the left is only about 45 years young, it is quite similar to the first universal testing machine produced by Tinius Olsen in 1880. Contrast this with the Super "L" in the foreground which dramatically illustrates the tremendous strides made by Tinius Olsen in recent years, with such outstanding features as:

- **dependable hydraulic loading with precision control.**
- **instantaneous load indication on the large Select-range dial indicator.**
- **three ranges indicated on the same dial with exclusive range color coding.**
- **ability to change ranges at will during test with the flip of a switch.**

Notice the masked clock in the photograph showing the total time for a typical tension test with the Super "L"—less than 1/5 the time required by the old, but still usable Olsen. Both of these testing machines are playing important roles in the Raymond G. Osborne Laboratories in Los Angeles.

For full information about modern Tinius Olsen Super "L" UTMs, write today for a copy of Bulletin 47.

Leadership in Testing Since 1880.

TINIUS OLSEN
TESTING MACHINE COMPANY
2010 EASTON ROAD • WILLOW GROVE, PA.
Testing and Balancing Machines

Trademark
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For more information, turn to Reader Service card, circle No. 393

What's new IN MATERIALS

test requiring that paint films on a steel panel do not ignite when heated electrically to 2300 F for 30 sec.

Hooker says paint manufacturers are now producing and marketing alkyd resin formulations of this new type in a variety of colors for general use on metal and wood surfaces.

The semigloss enamel is said to provide the excellent appearance, wearability, scrubbability and other desirable qualities associated with conventional alkyd-type paints. It shows no visible evidence of wrinkling or other film defects after air drying.

According to Hooker, the new enamel has an important advantage over previously available fire retardant paints in that mineral spirits —instead of relatively toxic xylene and turpentine—may be used as a thinner and solvent. **KEY NO. 633**

Insulating Varnishes for Class F Uses

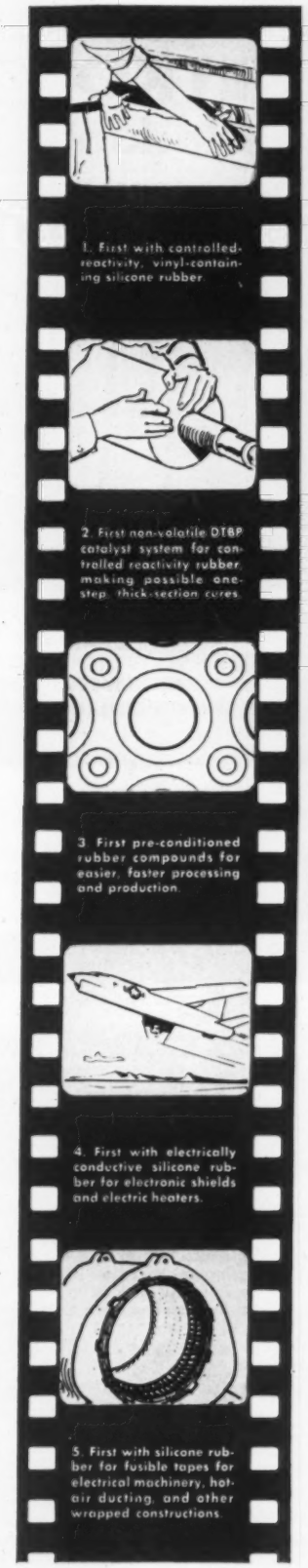
Two new polyester insulating varnishes have been introduced recently for Class F (310 F) electrical applications.

▸ One is a modified polyester that can be cured at baking temperatures commonly used for organic, heat reactive varnishes. The developer, Westinghouse Electric Corp., Micarta Div., Hampton, S. C., says that the cured varnish provides high dielectric strength and good resistance to moisture, oils and acids. Drying time is 15 min at 275 F.

The varnish is said to meet military specification MIL-V-1137A, Grade B, Type M. It can be supplied with a high solids content, making it suitable for impregnation by vacuum and pressure. **KEY NO. 634**

▸ The other new polyester insulating varnish was developed by General Electric Co., Schenectady 5, N. Y. It

USE THE 'SELECTOR'—You will find properties of most engineering materials, plus names and addresses of suppliers, in M/DE's *Materials Selector* reference issue, published last October.


1. First with controlled-reactivity, vinyl-containing silicone rubber.
2. First non-volatile DTBP catalyst system for controlled reactivity rubber, making possible one-step, thick-section cures.
3. First pre-conditioned rubber compounds for easier, faster processing and production.
4. First with electrically conductive silicone rubber for electronic shields and electric heaters.
5. First with silicone rubber for fusible tapes for electrical machinery, hot-air ducting, and other wrapped constructions.
6. First with silicone rubber compound for direct feed from carton to extruder.
7. First complete silicone rubber masterbatch system enabling fabricator to design his own compounds.
8. First commercial silicone compound for high altitude oxygen masks.
9. First and only silicone rubber compound qualified for automotive rear pinion seal.
10. First silicone rubber compound to meet strict naval cable specifications for atomic submarines.

SOME SILICONE RUBBER "FIRSTS"...WHERE YOUR SILICONES MAN PLAYED THE LEAD

The combined technical and research facilities of Union Carbide Corporation, with tremendous resources of chemical experience and knowledge, have brought about outstanding achievements in silicone rubber. Ten of these contributions, which industry has enthusiastically accepted, are depicted on our film strip here.

Important thing to remember: Whenever you need the strikingly superior advantages of silicone rubber, see your UNION CARBIDE Silicones Man first. Advantages such as low temperature flexibility, thermal and oxidation stability at very high temperatures; low compression set; weather, ozone, oil resistance; electrical resistance or conductivity. Your Silicones Man has them all at his fingertips. Write Dept. HM-9002, Silicones Division, Union Carbide Corporation, 270 Park Avenue, New York 17, N.Y. *In Canada:* Union Carbide Canada Limited, Bakelite Division, Toronto 12, Ontario.

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UNION CARBIDE SILICONES

For more information, turn to Reader Service card, circle No. 420

No. 16 of a series

Eastman 910 Adhesive solves another production bottleneck

The A. W. Haydon Company, Waterbury, Connecticut, makes a newly-designed timing device for automatic telephone switchboards.

The nylon timer gears and associated cams had to be molded separately due to their complex shape, then joined on an assembly-line.

Fast-setting, high-strength Eastman 910 Adhesive proved to be the economical, easy-to-use means of bonding these nylon parts.

In assembly, the gear and cam are held in a simple jig and a drop of adhesive is applied. The mating surfaces are brought together and held for a few moments. *Within 10 seconds a strong bond is formed, and the part is assembled into the timer.*

Eastman 910 Adhesive is making possible faster, more economical assembly-line operations and new design approaches for many products. It is ideal where extreme speed of setting is important, or where design requirements involve joining small surfaces, complex mechanical fasteners or heat-sensitive elements.

Eastman 910 Adhesive is used as it comes. No mixing, no heating. Simply spread the adhesive into a thin film between two surfaces. Light manual pressure triggers setting. With most materials, strong bonds are made within minutes.

What production or design problem can this unique adhesive solve for you?

Bonds Almost Instantly with Contact Pressure
No Heat...
No Catalyst...

For a trial quantity (⅓-oz.) send five dollars to Armstrong Cork Co., Industrial Adhesives Div., 9108 Dunbar Street, Lancaster, Pa., or to Eastman Chemical Products, Inc., Chemicals Div., Dept. E-8, Kingsport, Tenn. (Not for drug use)
See Sweet's 1960 Prod. Des. File, 7/E

For more information, circle No. 419

What's new IN MATERIALS

is the latest addition to the company's Alkanex line of insulating varnishes, and is reported to have higher heat resistance than any other polyester wire enamel. GE's wire enamel withstands temperatures up to 350 F; normal heat resistance for Class F wire enamel is 310 F.

A key feature of the new enamel is said to be its excellent runability, enabling it to be applied to all shapes and sizes of magnet wire. Other features are improved dielectric strength and good Freon resistance, making it suitable for hermetic motor applications.

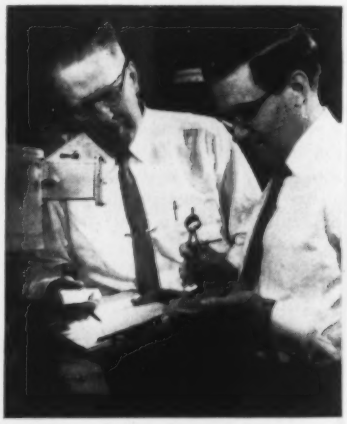
The producer says cut-through values of the enamel are significantly higher than those of other polyester wire enamels. Tests show cut-through values range from 550 to 600 F. **KEY NO. 635**

Lubricant Has Good Load-Bearing Capacity

An improved solid film lubricant is said to have about 20 times more load-bearing capacity than conventional solid film lubricants.

The improved lubricant was obtained by adding various inorganic sulfides to molybdenum or to tungsten disulfide. It is still under development.

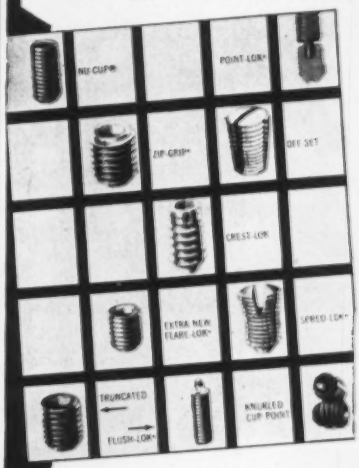
The effect of the additives was discovered by A. J. Haltner and C.



***Friction measurements** on new solid film lubricant are checked by A. J. Haltner and C. Oliver of GE's Research Laboratory.*

SETKO self-locking set screws

WIN FOR YOU EVERY TIME!



ONE OF THESE NUMBERS COULD BE YOUR WINNING ANSWER TO:

- **Increased product reliability**
- **Lower costs**
- **More dependable performance**

Whatever your requirements demand — better holding power, resistance to vibration, ease of application, etc.—chances are you'll find the *right* answer among the many types of self-locking set screws made by Setko. Many of the styles illustrated here can be combined with various head styles, points or locking actions to give you a set screw that will fit your *specific needs best*, at the lowest cost.

Why not join the hundreds of companies who have been winning lower costs and better product performance with the exclusive holding characteristics of Setko self-locking set screws?

SEND FOR FREE SELECTOR CHART AND TEST SAMPLES!

Exclusive Setko self-locking set screws selector chart lists over 1,001 possible combinations. Write for your copy and test samples.

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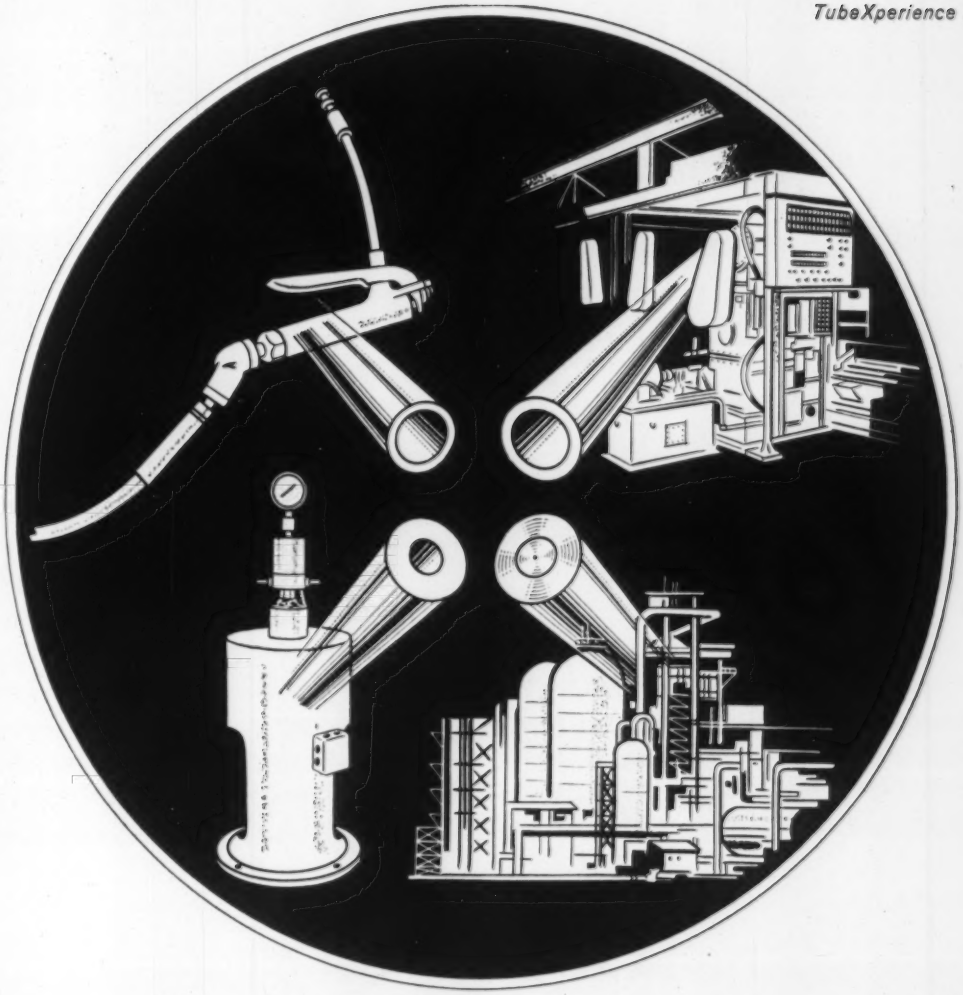
For more inforamtion, circle No. 369



Superior tubing makes pressures behave

whether 125, 5000, 30,000 or 100,000 psi

Superior small-diameter tubing makes pressures behave whether low, medium, high or super. Superior pressure tubing can be roughly divided into two groups: commercial pressure tubing for use in a range up to 20,000 psi; premium super pressure tubing to handle pressures from 15,000 to 100,000 psi. Both ranges can be handled effectively by a number of different analyses, depending on service requirements. Typical applications for Superior general-purpose pressure tubing include pressure tools, machine tools, heat exchangers and condensers. Superior super-pressure tubing is found in hydrogenation process equipment, high-pressure autoclaves, and pilot plant installations in chemical and oil refining plants.

All Superior pressure tubing offers many advantages. It helps prevent critical failures and downtime. It assures long service life, high fatigue strength, excellent corrosion and chemical resistance. In the range from 15,000 to 100,000 psi, Superior super-pressure tubing is a premium product. It is produced from specially selected raw materials. Inside surfaces are conditioned to remove fissures and other defects. During processing, special degreasing operations are performed, and the inside diameters are conditioned to insure a clear, smooth surface. Two types are available: a single wall mechanical tubing and a double wall, or composite unit, made from two thinner tubes. It is produced in an annealed condition and in ⅛ hard temper, and to mechanical properties specified by the customer. All Superior pressure tubing is 100% hydrostatically tested to recommended working pressures, and rigidly inspected for defects.

We can probably help you with any tubing problem that may confront you . . . in pressure, super-pressure or other applications. Contact us and feel no obligation. Superior Tube Company, 2006 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

For more information, turn to Reader Service card, circle No. 338

Solid Platinum Anode Performance at 1/10th the Cost

PLATANIUM® ANODES

PLATANIUM ANODES, made from titanium mesh coated with a uniform thickness of platinum by the PLATANEX* Plating Process, are equal functionally to solid platinum anodes yet cost less than 1/10th as much.

Thanks to a unique diamond configuration design, PLATANIUM ANODES give maximum anode area while cutting down over-all size 50% or more.

PLATANIUM ANODES are recommended for a wide range of electrolytic operations—from electroplating to refining or chemical processing—wherever insoluble anodes are indicated.

We're in full production and can offer immediate shipment of PLATANIUM ANODES in practically any size or quantity required.

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*Trademark, patent applied for.

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INDIUM — a high performance bearing metal — increases strength and hardness of bearing. It improves significantly resistance to corrosion by acid from lubricating oils and permits bearing surface to retain oil film better. Where high oil temperatures are encountered, it exhibits longer bearing life.

The high anti-seizure properties of lead-indium bearings make them ideal for heavy or high speed service where dependability and long life are essential. These bearings are now used in most European cars and in many aircraft and diesel engines in both Europe and North America.

INDIUM — a constituent for low melting-point alloys — Wood's metal plus 19% Indium melts at 117°F. Such alloys can be used for foundry patterns, fusible safety links and plugs and many other applications.

INDIUM — a solder material — Indium wets most metals and non-metals making it and many of its alloys a specialized solder for many applications, including glass-to-glass or glass-to-metal seals.

Cominco produces TADANAC Brand INDIUM in a variety of shapes including ingots, plates, wire and ribbon. Standard Grade Indium is 99.97% pure. Can its special qualities be of use to you? Inquiries are invited regarding the application of this versatile metal to your needs. Send for our brochure TADANAC Brand INDIUM.

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For more information, turn to Reader Service card, circle No. 345

What's new IN MATERIALS

S. Oliver of the General Electric Research Laboratory, Schenectady, N. Y.

How lubricant performs

Tests show that an unmodified molybdenum disulfide lubricant withstands a ¼-kg load when used to lubricate a ⅛-in. dia chromium alloy steel hemisphere that is sliding over a mild steel surface. However, when silver sulfide is incorporated in the lubricant, the load-bearing capacity increases to 5.3 kg. Haltner and Oliver say even better results are obtained when the improved lubricant is used on relatively hard surfaces such as chromium.

The effects of the inorganic sulfides can be noted at relatively low concentrations. During tests conducted thus far, the sulfides were added in quantities of approximately 10% by weight.

Additives decompose to form iron sulfide

The most effective sulfides investigated to date are those of anti-

Flame retardant laminate—In a standard flame retardency test (ASTM D635-56T) ⅛-in. thick specimens of a new epoxy-glass laminate extinguished themselves in 2 sec after the flame was removed. The laminate is called No. 6097 Lamicoid and is available from Mica Insulator Div., Minnesota Mining & Mfg. Co., Schenectady 1, N. Y.

The developer says the laminate, unlike many flame retardant laminates which are hard and brittle, is readily fabricated by conventional techniques.

The product is supplied in 36 by 42 in. sheets, in thicknesses ranging from 1/64 to 2 in. It is also available under the trade name CuClad with 1 or 2 oz copper foil bonded to one or both sides. **KEY NO. 636**

The seams don't show

Beautiful fit, beautiful look, beautiful soft drink dispenser. Beautiful job of close tolerance molding by General American. Working from wooden patterns, General American engineers designed six individual moldings. The shrinkage of each separate part was calculated to the thousandths of an inch. General American made the tools with the same precision.

Result—when this soft drink dispenser is assembled the seams are practically unnoticeable. In addition, the selection of the proper plastic, combined with General American's skill in molding, provides a product with very good luster, high impact properties, excellent stain resistance—and a reasonable price tag.

If you have a part or product that could or should be made of plastics, consult General American. In plastics, *it pays to plan with General American.*

in this 6-piece soft drink dispenser

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SPEER Carbon Co

Carbon Products Division
St. Marys, Pennsylvania

For more information, circle No. 444

What's new IN MATERIALS

mony, platinum, mercury, silver, titanium and lead. When used to lubricate iron or steel surfaces, such additives apparently decompose to produce a layer of iron sulfide on the metal surface. This layer is believed to have better lubricating properties than the original metal, and may interact advantageously with the lubricant itself. The mechanism by which the additives improve lubrication may be similar to that which is effective when extreme-pressure additives are used in liquid lubricants, according to Haltner and Oliver.

New Sheet Glass Is Free from Distortions

New manufacturing techniques have enabled Pittsburgh Plate Glass Co., 632 Ft. Duquesne Blvd., Pittsburgh 22 to develop a sheet glass that is said to have "remarkable freedom from distortion."

Called Premium Pennvernon, the product is made by a technique in which molten glass is formed into sheets without being touched by any mechanical device to mar its surface.

The product is supplied in all standard thicknesses of window and heavy sheet glass. It is priced the same as regular "A" quality sheet glass. KEY NO. 637

Urethane Coating Gives Better Patent Leather

Wilmington Enameling Co., P. O. Box 66, Wilmington 99, Del. has developed a new type of patent leather called Helios. Basically, the product consists of 1) a chrome-tanned leather substrate, 2) a linseed oil gel coating, and 3) a two-component type urethane coating that is built up to a total thickness of 2.4 to 3.7 mils when dry. Each coating is oven dried overnight.

The new type of patent leather is very glossy and smooth. It has higher elongation and tensile strength, and better flex life, than conventional linseed oil-coated leather (see accompanying table). The product is also said to have excel-

You can change a complete set of clamps on a Scott Tester...in a matter of seconds!

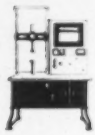
Here's how:

2 sec. Locking pin out — top clamp off.

4 sec. New clamp in position — pin replaced.

6 sec. Locking pin out — bottom clamp off.

8 sec. New clamp on — pin replaced — locking collar tightened. That's all — start testing!



With Scott's new quick-change clamp assembly, you speed up your test operations and get more tests per day. This is another reason why Scott Model CRE Constant-Rate-of-Extension Tester makes good sense and good savings in the laboratory or in production.

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PROPERTIES OF URETHANE AND LINSEED OIL-COATED LEATHERS

Leather Coating →	Linseed Oil	Urethane Resin
Ten Str, psi	400	1200
Elong, %	20-40	100-150
Heat Dist Pt, F	415	465
Refractive Index	1.4582	1.5194
Flex Life (cycles before checks develop)	10,000	200,000

lent resistance to water, detergents, solvents, sunlight and mild alkalis.

Previously, patent leather was made by applying three coats of linseed oil to chrome-tanned leather. The linseed oil was processed to various viscosities by cooking.

KEY NO. 638

Impregnated Fabrics Withstand 2500 F

A new process for impregnating any textile material or fabric with aluminum has been developed by Baxter, Kelly & Faust, Inc., C and Tioga Sts., Philadelphia 34.

The process (details not revealed) is claimed to permit a fabric to retain its original strength, texture, design and flexibility while making it resistant to temperatures up to 2500 F. Fabrics can be impregnated on one or both sides.

The developer expects aluminum-impregnated fabrics to be used in a variety of applications, including heat resistant safety gloves and aprons, fireproof draperies, heat resistant curtains for industrial furnaces, and space suits.

KEY NO. 639

Molybdenum Alloy Has High Melting Point

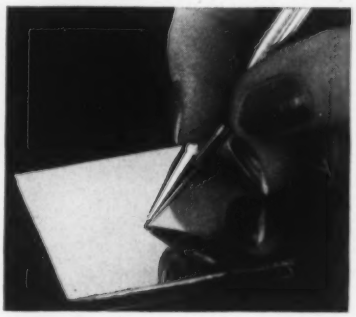
A 70 molybdenum-30 tungsten alloy called Climelt is now commercially available from Climax Molybdenum Co., Div. of American Metal Climax, Inc., 500 5th Ave., New York 36. The material has a higher melting point (5100 F) than unalloyed molybdenum (4760 F).

The alloy, which is designed for

LOF GLASS

Notes on
VACUUM-DEPOSITED COATINGS

Front-surface mirrors coated with aluminum give perfect reflection without double images

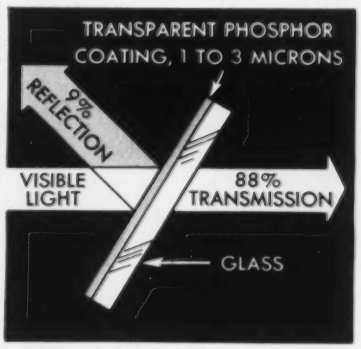


Front-surface mirrors recommended for optical, commercial and scientific uses are among the vacuum-deposited coating products supplied by Liberty Mirror.

These front-surface mirrors give a perfect single reflection. Back-surface mirrors may reflect a second image from the front surface of the glass. The reflective aluminum deposit is coated with hard quartz to increase durability.

Applied to glass, metal or plastic, vacuum-deposited coatings are used in such varied applications as toys, cameras, pin setters, wheel-alignment equipment, aircraft or missiles.

Transparent phosphor coating illuminates with extreme resolution



Liberty Mirror's evaporated coating technique gives this phosphor coating excellent resolution capabilities for use in electronic projection applications. The coating has a light output of 15 foot lamberts or greater, at a power dissipation level of 25 milliwatts with peak output using a screen voltage up to 15 kv.

For assistance in solving application problems, write Liberty Mirror Div., Libbey-Owens-Ford Glass Company, 811 Madison Ave., Toledo 1, Ohio.

For more information, circle No. 415

Just Published **The definitive work on a great originator . . .**

by ROBERT MARKS

THE DYMAXION WORLD OF BUCKMINSTER FULLER

HERE IS A FASCINATING study of the life and work of R. Buckminster Fuller—one of the most original and controversial men of our time. Since their first meeting some 18 years ago, Robert Marks has been an enthusiastic advocate and interpreter of Fuller's structural concepts. In this book he explains even the most complex of Fuller's ideas in a way that makes them accessible to all readers.

Way back in 1938 another originator, Frank Lloyd Wright, addressed Fuller as "the most sensible man in New York." In the delineation of his subject's life and philosophy, Mr. Marks reveals a man whose foresight and energy would naturally gain the attention and respect of other great innovators.

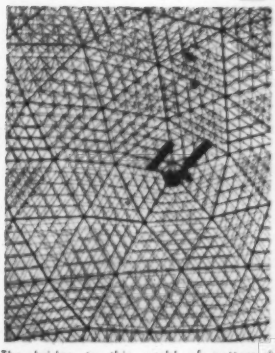
When the book's narrative moves from the man to his work, it takes the reader on the most complete tour of the Dymaxion world ever devised. Included are all the provocative Dymaxion projects that were 25 years ahead of their time—4D house, deployment units and transports, as well as Fuller's more recent work on Geodesic domes and space frames. The book also reveals the "total design" principles behind all these highly original concepts.

In addition, the pattern of thinking which evolved a system of geometry—Energetic and Synergetic—and a new system of map-making, is brilliantly analyzed.

The book is splendidly illustrated with over 350 fully captioned photographs and drawings that graphically depict the plans and structures, the today and tomorrow in Mr. Fuller's Dymaxion world.

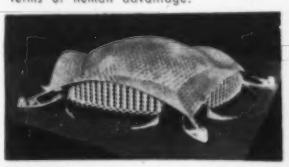
A major portion of the illustrations appear in their own sections. Here are the topics of these sections, many of which are several pages each.

ILLUSTRATION SECTIONS: Astor Plane; Stockade System; Multiple-Deck 4D House: Air Ocean World; Dymaxion House; Dymaxion Bathroom; Dymaxion Transport; Mechanical Wing; Dymaxion Deployment Unit; Dymaxion Dwelling Machine; Synergetic-Energetic Geometry; Maps and Charts; Tensegrity; Octet Truss; Minor Inventions; Autonomous Package; Geodesic Invention and Development; Skybreak Dwellings; Ford Dome; Seedpod Foldable Geodesics; U. S. Marine Corps Geodesics; Radomes; Paperboard Domes.



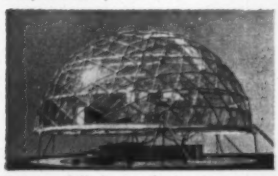
The bridge to this world of patterned abundance is what Fuller calls "Comprehensive Design." The book reviews this kind of design and what it means in terms of human advantage.

The book interprets the man responsible for the dymaxion world: his philosophy, background, and significance.

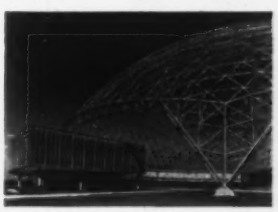


Thoroughly depicts the most famous of Fuller's creations, the dome. Includes those used by concert halls, sports palaces, industry, agriculture, banks, societies, to name just a few.

Includes all building types—their uses, design, materials, methods of construction, etc.



Presents Fuller's prophecies—transparent domes that cover entire cities for climate control; submarine islands; temporary, disposable dwellings.

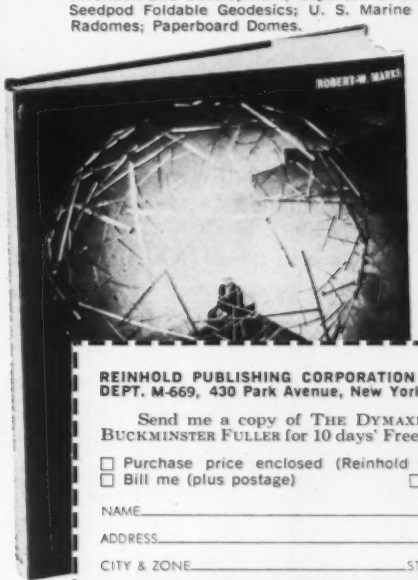


Provides an incomparable visual record from earliest designs to current projects under construction.

Explains the Fuller vocabulary with pictorial examples: energetic-synergetic, tensegrity, geodesic, dymaxion, dwelling machine, octet truss, and 4D.

Covers the entire gamut of Fuller achievements—buildings, transports, geometry, cartography, deployment units, and many others.

Provides a complete, visual record of Fuller's work . . .
Over 350 photographs and drawings, fully annotated —
Here are just a few reduced samples of the exciting illustrations with which the book abounds. Each one is numbered and explained in corresponding paragraphs. These illustrations alone provide an important historical record of Fuller's work.



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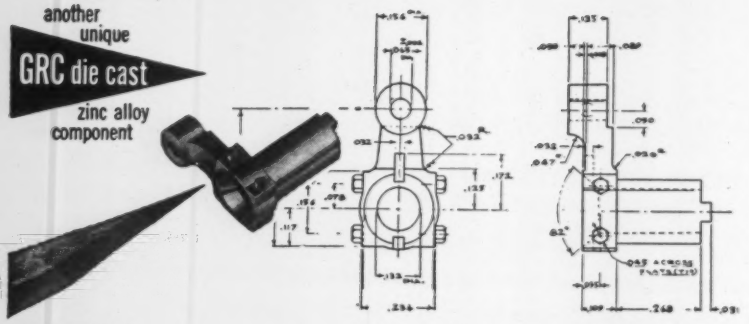

GRC die casting helps Lionel achieve tiny part authenticity

This intricate toy crank was die cast in zinc alloy by GRC in a single automatic operation. Cost? Little more than $5.00 per thousand in lots of 500,000. Result? Produced quicker and more economically than Lionel could themselves. Less than half an inch overall, it is typical of the many small (maximum is 1¾" ½ oz., no minimum) parts problems solved by GRC's unique techniques. Gries' specialized machines deliver parts ready for use—uniform, accurate, clean—no trimming, no assembly, no scrap loss.

If you have a small parts problem, write, wire or phone for GRC's die casting bulletin or send prints for quotation.

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Coming in November . . .

1961 MATERIALS SELECTOR

The year's biggest boon to those time-pressed engineers, designers, and other technical men who select and specify engineering materials, forms and finishes! This new MATERIALS SELECTOR will be more than 60 pages bigger than last year's edition.

All editorial pages in the MATERIALS SELECTOR are in data sheet form to provide you with quick comparisons of properties and applications of hundreds of metals; nonmetallics; forms and shapes; finishes and coatings; and joining and fastening of materials. Keep the SELECTOR on your desk for ready reference. You'll find it a real time saver.

The MATERIALS SELECTOR is available to *Materials in Design Engineering* subscribers only. It is not sold separately.

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What's new IN MATERIALS

PROPERTIES OF CLIMELT*

Tensile Strength, psi	
72 F	121,500
1800 F	65,700
Yield Strength (72 F), psi	106,900
Elongation, %	
72 F	26
1800 F	25
Reduction of Area, %	
72 F	40
1800 F	77

*Stress relieved at 2000 F.

high temperature service, has a theroretical density of about 0.43 lb per cu in.

Climelt has been successfully forged at 2300 F. Climax says the alloy requires more reheating and higher working pressures than does unalloyed molybdenum.

The material can be machined by conventional and spark-discharge methods. **KEY NO. 640**

Other News . . .

Plastics

▸ A flame resistant epoxy compound called No. 1202 is being marketed by Epoxy Products, 137 Coit St., Irvington, N. J. It is supplied as a liquid epoxy resin, or as molded cylindrical and square shells, and custom molded parts. **KEY NO. 641**

▸ In a new glass and Dacron-based epoxy tubing available from Westinghouse Electric Corp., Micarta Div., Hampton, S. C., an inner wall of glass cloth and epoxy resin and an outer wall of Dacron cloth and epoxy resin are bonded together to form an integral tubular structure. The tubing is supplied in lengths up to 36 in., in wall thicknesses of 3/64 in. and above. **KEY NO. 642**

▸ A technique that might make multi-colored highways and airport pavements practical for the first time was disclosed recently by Esso Research & Engineering Co., 15 W. 51st St., New York 19. The method involves compounding plastics materials with rock or sand to form about a one-inch thick colored upper layer or surface of pavement. **KEY NO. 643**

▸ An expanded TFE tubing shrinks to form a tight fit on electrical and other parts when heated. The tub-

Answers a multitude of engineering questions . . .

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SPE Plastics Engineering Series

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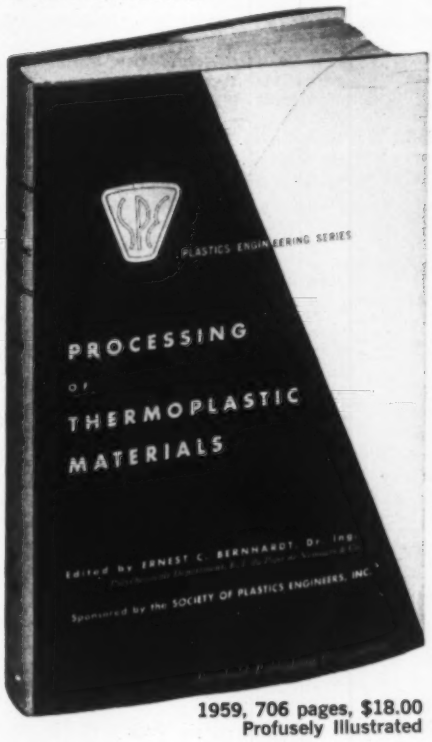

1959, 706 pages, $18.00
Profusely Illustrated

Edited by **E. C. BERNHARDT,** Dr. Ing.,
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Here is a definitive, and the most extensive handbook ever published on the engineering problems involved in extrusion, injection molding, calendering and other thermoplastics processing operations. The book reviews the engineering fundamentals on which the design of plastics processing equipment is based, and demonstrates the practical application of these fundamental concepts in the analysis of thermoplastics processing problems. The text is developed simply and clearly, and is designed to help fill the need for a basic book on processing of thermoplastics. The book is aimed at engineers, but does not require the reader to possess previous knowledge of plastics processing technology.

Twenty technical authorities have contributed to this volume from first-hand experience, and fourteen plastics firms and universities have supported it by providing information, editors and authors.

Partial Contents and Contributors

SECTION I—Fundamentals

Flow Behavior—A. B. METZNER, Sc. D., University of Delaware
Heat Transfer and Thermodynamics—J. M. McKELVEY, Ph.D., Washington University, St. Louis
Mixing and Dispersing—W. D. MOHR, M.S., Massachusetts Institute of Technology

SECTION II—Applications

Extrusion—J. B. PATON, B.S.; P. H. SQUIRES, Ph.D.; W. H. DARNELL, Ph.D.; and F. M. CASH, B.S.: all of E. I. du Pont de Nemours & Co., Inc. and J. E. CARLEY, Ph.D., Modern Plastics, Breskin Publications, Inc.
Injection Molding—G. B. THAYER, B.S.; J. W. MIGHTON, B.S.; R. B. DAHL, B.S.; and C. E. BEYER, B.S. All of Dow Chemical Co.
Calendering—D. I. MARSHALL, Ph.D., Union Carbide Plastics Co.
Mixing and Dispersing Process—J. T. BERGEN, M.S., Armstrong Cork Co.
Sheet Forming—N. PLATZER, Ph.D., Monsanto Chemical Co.
Forming and Hollow Articles—G. P. KOVACH, Dipl.-Ing., Foster-Grant Co.
Sealing and Welding—B. P. ROUSE, JR., Ph.D. and T. M. HEARST, B.S., both of Tennessee Eastman Co.

SECTION III—Processing Properties

Processing Properties—R. F. WESTOVER, M.S.E., Bell Telephone Laboratories

About the Editor

ERNEST C. BERNHARDT supervises process development activities at the Sales Service Laboratory of the Polychemicals Department, E. I. du Pont de Nemours and Company, Inc. His technical publications have been primarily in the field of thermoplastics extrusion. He is a member of the Society of Plastics Engineers, and of the American Chemical Society. He received a B.S. in Chemical Engineering from Purdue University, his M.Ch.E. from the University of Delaware, and a Doctorate in Engineering from the TECHNISCHE HOCHSCHULE in Darmstadt, Germany.

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ing, available from Pennsylvania Fluorocarbon Co., Inc., 1115 N. 38th St., Philadelphia 4, is supplied in thin and standard walls.

KEY NO. 644

Other nonmetallics

▸ Silicones Div., Union Carbide Corp., 270 Park Ave., New York 17, has announced that its solventless silicone resin for high temperature insulation is now commercially available. Formerly marketed under the experimental designation Y-2090, it is now sold as XR-65. KEY NO. 645

▸ A refractory brick containing approximately 75% silica is said to withstand temperatures up to 2600 F or more. The brick, called Sem-Sil, was developed by Refractories Div., H. K. Porter Co., Inc., Porter Bldg., Pittsburgh 19. KEY NO. 646

▸ Felt Products Mfg. Co., 7450 N. McCormick Blvd., Skokie, Ill. is marketing a new compound designed for lubricating and sealing bolts, studs and flanges at high pressures and at temperatures up to 1800 F. The product, called Fel-Pro C5-A, is said to stop galling and seizing of threaded surfaces. KEY NO. 647

Finishes

▸ A rust inhibiting compound that is said to give long-lasting corrosion protection to new metals, fabricated parts, machinery, tools and other forms of iron and steel is now being marketed by Brad Chemical, Inc., 111 W. Washington St., Chicago 2. It is called Poly-Rustex. KEY NO. 648

▸ New temperature indicating materials, Thermocron crayons and DetectoTemp paints, are being marketed by Air Reduction Sales Co., Div. of Air Reduction Co., Inc., 150 E. 42nd St., New York 17. The temperature measuring devices are said to accurately indicate the temperature of any hot surface by distinct changes in color. KEY NO. 649

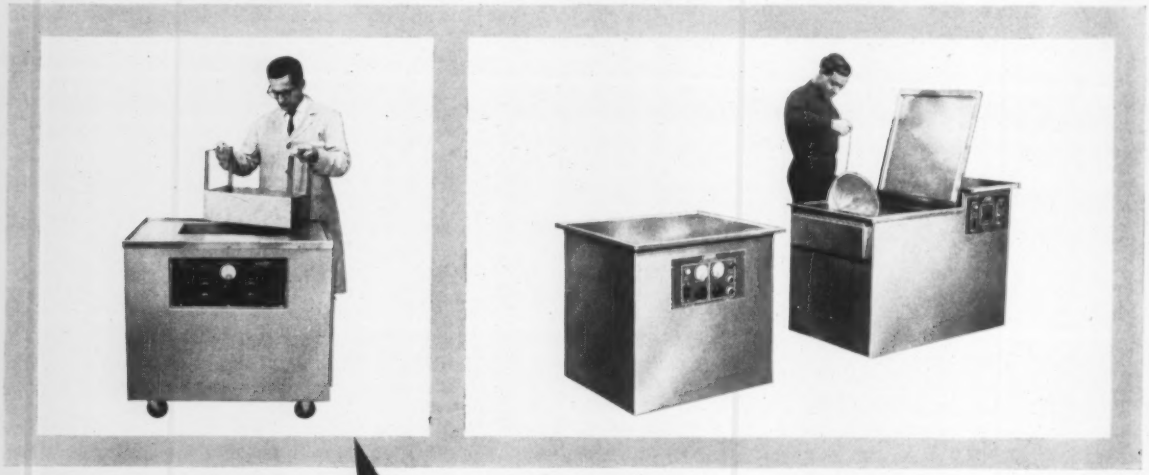
▸ Mitchell-Bradford Chemical Co., Wampus Lane, Milford, Conn. recently announced three new metal finishing products for the treatment of aluminum. No. 22 cleans and chemically etches aluminum and aluminum alloys; Al-Smut removes smut from most types of aluminum; and Cleaner No. 20 cleans aluminum without etching. KEY NO. 650

▸ An epoxy marking ink that is said to resist the effects of such cleaning solutions as xylene, toluene and methyl alcohol is available from Melpar, Inc., 3000 Arlington Blvd., Falls Church, Va. The ink, called Mel-Ink M-100, can be used to identify nomenclature on glass dials, printed circuit boards and magnetic tapes. KEY NO. 651

▸ A plastics release coating for paper and fiber containers has been developed by Resisto Chemical, Inc., Dri-Dux Div., P. O. Box 1945, Wilmington 99, Del. Known as Tar-Dux, the new coating prevents such materials as asphalt, butyl rubber, tar, adhesives, resins and waxes from adhering to their containers. KEY NO. 652

Joining

▸ A method for joining polyester film, tape and sheet without heat or adhesives has been developed by International Ultrasonics, Inc., 1697 Elizabeth Ave., Rahway, N. J. Joining is accomplished by high frequency mechanical vibration which creates heat at the joint interface to form a bond. KEY NO. 653



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1 GLASS Its Industrial Applications

by CHARLES J. PHILLIPS, *School of Ceramics, Rutgers, The State University*

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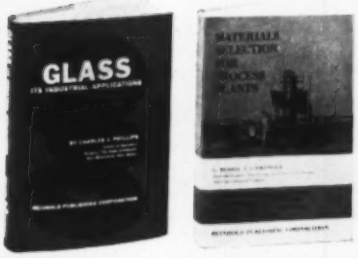
COVERS THE MANUFACTURE, physical and chemical properties, and the industrial applications of all types of glass. It is directed to the users—engineers, scientists, production and purchasing personnel—who are involved in the design, specification, testing, purchase or sale of glass products. The book reflects all the recent advances in the field and includes new information on such subjects as glass bead reflectorization and the "float glass" process for making flat glass. The order of topics has been arranged for maximum continuity so that each topic is preceded by everything needed to understand it. Here is a thorough, semi-technical approach to the subject which provides an up-to-date treatment of all phases of the manufacture and use of glass.



Covers metals, plastics, rubber, paints and cements . . .

2 MATERIALS SELECTION FOR PROCESS PLANTS

by RUSSELL E. GACKENBACH, *Materials Engineer, Engineering and Construction Division, American Cyanamid Company*

1960, 319 pages, $8.50

THIS PRACTICAL HANDBOOK goes directly to the problem of material selection as encountered by the engineering, maintenance and production personnel of process plants. The book contains all necessary data on metals, plastics, rubbers, paints and cements. The author discusses corrosion-resisting qualities along with the mechanical properties and fabricating characteristics that must be considered in selecting the most suitable and most economical material for a particular purpose. The information contained in the book is presented in non-technical terms to be of the greatest use to that large group responsible for obtaining longer production runs, increased down time, and decreased maintenance and engineering costs.

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by ROBERT E. WIECH, JR. and ROBERT F. STRAUSS, *Thiokol Chemical Corporation, Reaction Motor Division*

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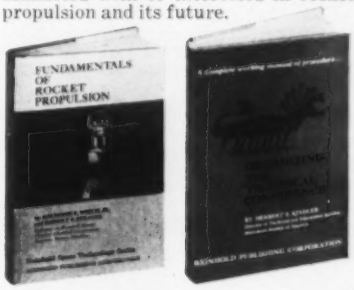
PROVIDES an all-inclusive review of the rocket engine—its history, fundamentals of operation, design of components and methods of application. The material contained in the book is neither overly technical nor trivial in its presentation and scope. Chapters advance one step at a time through the basic laws governing rocket engine design; the need for and probable design of future engines; and the rocket engine's job in space flight and satellite missions. The authors fully describe all rocket engine types so that the function and operation of each is clearly understood. All basic rocket formulas derive from algebra, rather than the more difficult calculus. Here is an ideal reference for guidance and electronics engineers, propellant chemists, chemical and mechanical engineers, metallurgists, students, or anyone remotely connected with or interested in rocket propulsion and its future.



A complete working manual of procedure . . .

4 ORGANIZING THE TECHNICAL CONFERENCE

by HERBERT S. KINDLER, *Director of Technical and Educational Services Instrument Society of America*

1960, 160 pages, $6.00

THIS IS MORE than a book about holding technical conferences; it is a working manual that clearly charts the duties and activities of the organizing committee. It answers completely the questions of when to initiate, and how to plan, organize and conduct effective technical conferences, whether large or small. All facets of programming, promoting, documenting, administering and evaluating professional meetings of all kinds (symposia, workshops, seminars, lectures, clinics and exhibits) are explained. The book also analyzes and interprets key factors that contribute to a successful conference. The author removes the burden of confusion from both the inexperienced and experienced conference organizer from beginning to end. Here is invaluable information for any group or organization that wants more effective conference communications.

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by RAYMOND N. AUGER, *Technical Editor, Automatic Control*

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by ROBERT MARKS

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What's new IN MATERIALS

(cont'd from p 126)

New Data on Iron-Base Superalloy

by John Bulina*

An iron-base superalloy, called W-545 and introduced by Westinghouse Electric Corp. in the spring of 1957 (see *Materials & Methods*, May '57, p 182), is presently available in a wide variety of shapes and sizes such as billets, bar, sheet, strip and wire.

Potential uses

The alloy, although slightly more difficult to process than the higher alloyed stainless steels, can be fabricated readily into turbine wheels, compressor disks, shafts, hubs, spacers and other turbine parts; skins, cone assemblies and fasteners for missiles and aircraft; retainer rings for generators; and pressure vessels.

The alloy, which is made by the consumable electrode vacuum melting method, is essentially an iron-nickel-chromium alloy with small additions of molybdenum, titanium and boron.

High temperature strength

As reported in the May '57 issue of this magazine, it is the addition of boron and its correlation with a relatively high titanium content that is responsible for the alloy's excellent high temperature strength.

Tests show the alloy withstands temperatures up to 1300 F at high stresses and up to 2000 F at low stresses. Specimens of W-545 heated to a temperature of 1200 F and subjected to a stress of 75,000 psi have survived for as long as 300 hr without breaking.

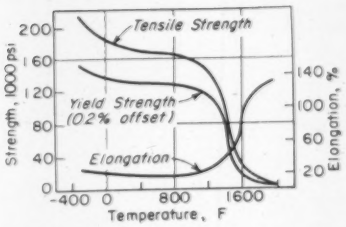
Notch ductility is another advantage of the alloy.

Role of boron in the alloy

The size of a boron atom is about three-fourths the size of usual substitutional elements (iron, nickel, chromium, cobalt, etc.) and is slightly larger than the size of interstitial elements (hydrogen, carbon and nitrogen). Because of this unusual size, boron atoms can play the role of both substitutional and inter-

COMPOSITION OF W-545 (%)

Carbon	0.08 max
Manganese	1.25-2.00
Silicon	0.10-0.80
Phosphorous	0.04 max
Sulfur	0.03 max
Chromium	12.00-15.00
Nickel	24.00-28.00
Molybdenum	1.25-2.25
Titanium	2.70-3.30
Boron	0.010-0.030
Aluminum	0.25 max
Copper	0.25 max
Iron	Balance



***Tensile properties** of W-545 alloy at various temperatures.*

*The author is associated with Westinghouse Electric Corp.'s Blairsville, Pa. Materials Manufacturing Laboratory.

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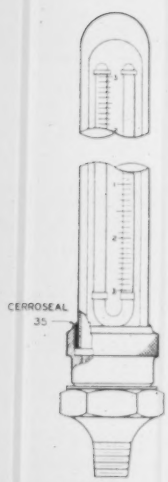

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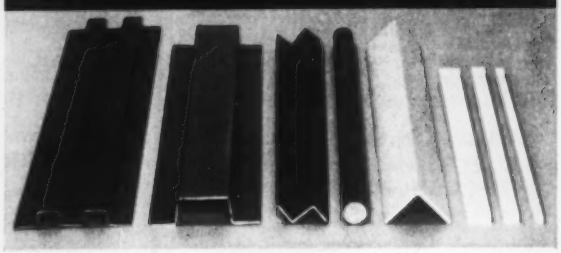

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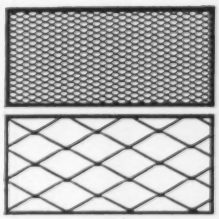

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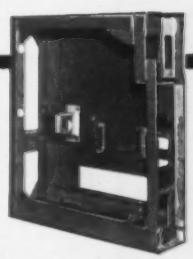

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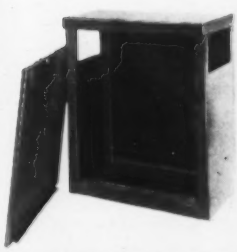

◀ **Welded Steel Electrical Cabinet Assembly** weighs 67 pounds. Dimensions, 25" x 14" x 30". 24 component parts. 24 tack welds, 36 spot welds, riveting and 6" of arc welding. Painted.

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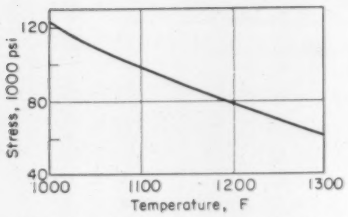
stitial elements, thus improving ductility, notch resistance and strength of the alloy.



***Stress rupture strength** (100 hr) of W-545 alloy at various temperatures.*

Two Materials Are Strongly Piezoelectric

Zinc oxide and cadmium sulfide are strongly piezoelectric, according to the results of recent tests performed by A. R. Hutson of Bell Telephone Laboratories, 463 West St., New York 14.

In order to demonstrate piezoelectricity, Hutson had to dope zinc oxide with lithium to neutralize the excess conductivity which has masked the effect until now. When this was done, the resistivity of the material was raised from 10^3 to 10^{12} ohm-cm at room temperature.

Piezoelectricity greater than that of quartz

Hutson found that the degree of piezoelectricity exhibited by the doped zinc oxide was about four times as great as that of quartz. Piezoelectricity exhibited by cadmium sulfide was twice that of quartz. Specifically, with dielectric constants of 8.2 and 9 for zinc oxide and cadmium sulfide respectively, electromechanical coupling coefficients were calculated to be approximately 0.4 for zinc oxide and 0.2 for cadmium sulfide, compared with 0.095 for quartz.

Hutson says the best electromechanical transducers for generating ultrasonic and radio frequencies are made from materials that are strongly piezoelectric. He says such materials exhibit a large electromechanical coupling coefficient. Accordingly, both zinc oxide and cadmium sulfide, as the result of the new findings, could conceivably be used in highly efficient electromechanical transducers for generating ultrasonic and radio frequencies.

Ferritic Stainless Steel Improved with Silicon

Oxidation resistance of ferritic stainless steel at high temperatures is enhanced by the presence of silicon in the material.

Research by J. F. Radavich, Dept. of Physics, Purdue University, Lafayette, Ind. shows that very little oxide scale forms on a ferritic stainless steel containing 3.55% silicon when exposed to temperatures up to 1800 F.

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THE LAST WORD

by H. R. Clauser
Editor

Are There Really Too Many Societies?

To all of you who have complained at one time or another that there are too many societies (which automatically leads to too many meetings), I recommend that you take a look at the Encyclopedia of American Associations. It probably will convince you that your remonstrations are well founded, for the encyclopedia lists over 10,000 different societies and associations.

Also, in the encyclopedia's preface you will find the following observations made by the Frenchman, de Tocqueville, over a century ago:

"The Americans of all ages, all conditions and all dispositions constantly form associations. They have not only commercial and manufacturing companies in which all take part but associations of a thousand other kinds, religious, moral, serious, futile, restricted, enormous, or diminutive. The Americans make associations to give entertainments, to found establishments for education, to send missionaries to the antipodes."

With de Tocqueville's words still fresh in my mind, I scanned a few of the encyclopedia's 700 pages, and here are a few of the listings I found.

Association of Piped Button Hole Manufacturers.
Association of Uptown Converters
Ancient Order Bagmen of Bagdad
National Slingshot Association
American Snowshoe Union
Cactus and Succulent Society of America
Mended Hearts Society
International Concatenated Order of Hoo Hoo.

As you can easily imagine from this sampling, there is hardly a cause or a thing not represented by an association. And, even though not listed in the encyclopedia, I am sure that at some time and somewhere several determined individuals have banded together to form either a Benevolent Society for Non-Joiners or a Society for the Prevention of More Societies.

Technical Recreation

Do you want to keep your boy out of smoke-filled pool rooms? You can help by lending your support to an unusual and, we believe, a worthwhile movement that has been developing over the past five years. Called "technical recreation," it is a strange sort of movement, because, as far as we can tell, there is no formal organization, no officers, no committees, no carefully laid plans, no dues, and no credit or recognition is sought for work done. Even the individual who sent us a booklet describing the program asked that he remain anonymous.

Briefly the aim of the movement is to extend youth recreational programs beyond physical and social interests to include scientific and technical activities. The booklet suggests many ways that this can be done. One suggestion to which you can all easily lend support is to pass on to a local recreation center copies of technical or trade magazines that you would otherwise discard. In some communities the education department, chamber of commerce or even the police department serves as a collection center and distributes the magazines.

If you would like further information in this technical recreation movement, drop me a card and I'll pass it along to the proper people.

What Is Our Age?

This age in which we live has been given many different names. Among others, it has been called the Atomic Age, the Space Age and the Age of Anxiety. Next month another name will be added to the list when we publish our 48-page special section titled "The Challenge of the Materials Age."

There is a good deal of justification for calling this present period the Materials Age. Most technical experts agree that our technological progress is critically materials-dependent. The rate of our advance in utilization of atomic energy and in our penetration of outer space is being largely determined by how fast and how well we can break through formidable materials barriers. The special "Materials Age" section next month will be, in large part, an appraisal of how industry, research, technical societies and education are preparing to meet this challenge to materials.

CELANESE MATERIALS REVIEW

- **FORTIFLEX linear polyolefins**
- **FORTICEL cellulose propionate**
- **ACETATE molding compounds**
- **ACETATE sheeting**
- **POLYESTER resins**

CELANESE TECHNICAL SERVICE

How to put more experts on your team without extra cost

Celanese has the technical experts who can help you get the most out of plastic materials at any stage from design to final product testing. Here's a rundown on the technical services Celanese can provide with respect to molding.

DESIGN CONSULTATION

In the final stages of a design, you can call on Technical Service to review the design from the standpoint of molding technology. At this point it is possible to forestall problems of moldability and strengthen critical points by simple means such as changing a radius—without affecting basic design.

ASSISTANCE WITH MOLD DESIGN

Celanese Technical Service is prepared to review mold designs and offer recommendations. This includes mold cooling, gate location, sizes of gates and runners, etc. It's surprising how much a slight variation from optimum in mold design can affect the quality of the molded piece. Form retention, surface quality, freedom from warping and sinks, demand a precise knowledge of the geometries involved as well as of the materials.

MATERIAL SELECTION

Literally dozens of basic formulations of the Celanese plastics exist, and new formulations are possible to meet the needs of molders. They vary in melt index, flow temperatures, molding properties, and end-use properties. Often, formulations are available for special needs, such as flame retardant or light stabilized properties. Here Celanese technical assistance is invaluable in coming up with formulation recommendations that will be most suitable for your product.

EQUIPMENT AND ITS ADAPTATION

Celanese Technical Service will be glad to discuss your equipment requirements or needed modifications. For example, you may benefit from their knowledge of auxiliary molding equipment, or cooling processes, or the details of molding machinery.

PILOT MOLDING SUPERVISION

Celanese technical experts will help you supervise the first run of material. If material difficulties arise at the molding trials, they will make suggestions for changes and cooperate with you on additional trials. If you desire, they will send samples of the molded parts to Celanese Service Laboratories for evaluation.

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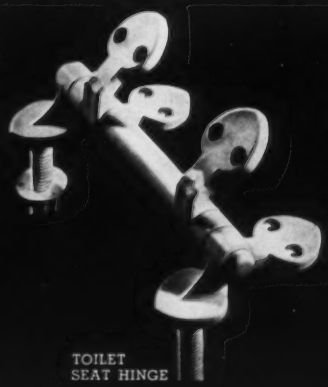

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PLASTICS and RESINS

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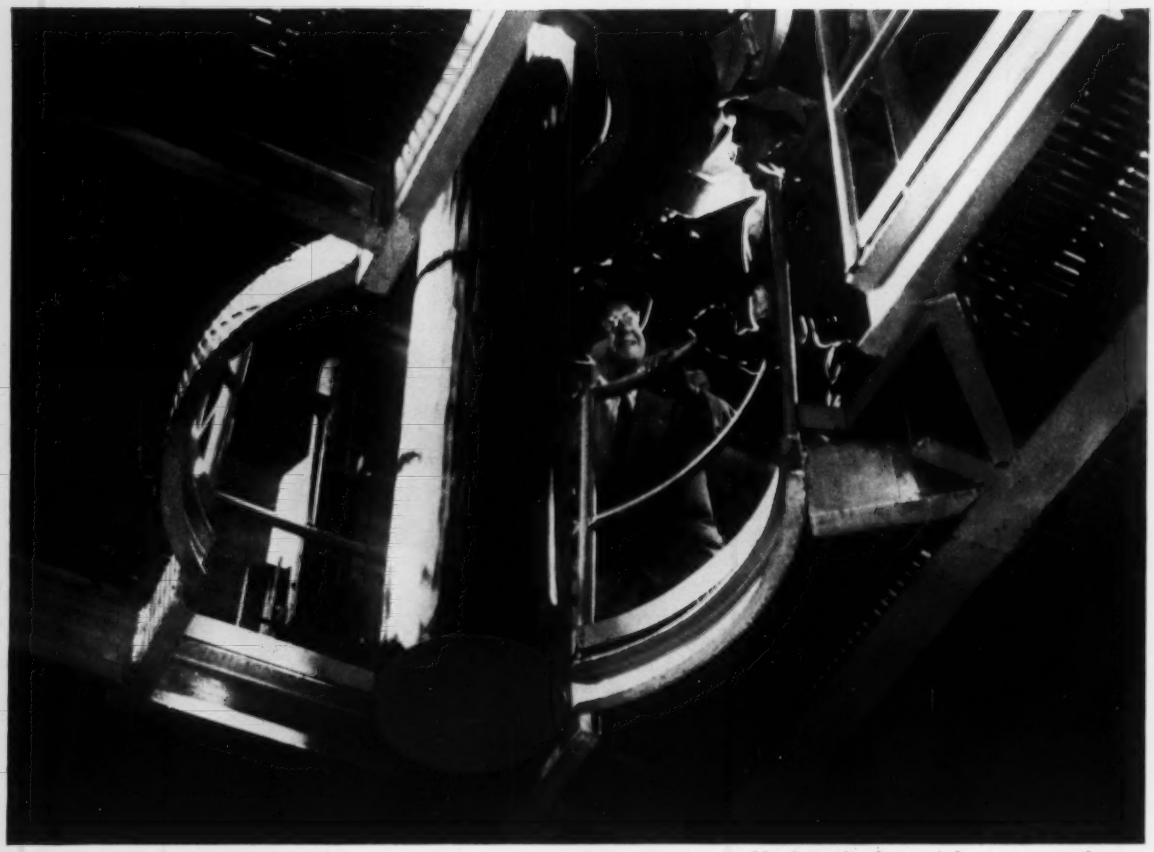

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